# INSTRUCTION MANUAL

# MOTOROLA

# MILLIVOLTMETER

S-1339A

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# CHAPTER I

## INTRODUCTION

### 1.1 General

This RF Millivoltmeter provides an accurate readout of measurements from the low radio frequencies to the gigahertz region, over a voltage range of 100 μV to 3 volts. It is a programmable, solid-state instrument of high sensitivity and accuracy, characterized by high input impedance (see Figures 1 and 2), excellent stability, and low noise.

It exhibits true rms response for input signals up to 30 millivolts, gradually approaching peak-to-peak above this level. The meter, however, is calibrated to indicate rms of a sine wave above 30 mV.

Input and output connections for external control and readout are provided by a 22-pin card-edge connector at the rear of the instrument.

A linear dc output, whose level is proportional to the rf input voltage, is also provided at a rear connector. This may be used to drive a recorder, remote indicator, or other analog devices.

The voltmeter offers a convenient and accurate means for making a wide variety of measurements. Typical uses of this instrument include:

In transistor testing the instrument may be used to measure $\beta$, $f_t$, and other transistor parameters.

VSWR and return loss measurement using bridge methods, directional couplers, and adjustable or slotted lines.

Gain and loss measurements in wide-band amplifiers, including such design characteristics as stage gain, flatness of the pass band, upper cutoff or corner frequency, negative feedback factors, and other parameters.

Proper adjustment of tuned circuits in narrow-band amplifiers.

The adjustment, measurement of performance, and evaluation of rf filter parameters.

Measurement of vswr or return loss and attenuation of rf attenuators.

Measurement of output levels of signal generators, adjustment of baluns, harmonic distortion of rf signals, and adjustment of circuits for minimum voltage (null) or maximum voltage (peak).

The standard features of the instrument are:

Remote programmability.

Measures from 100 µV to 3 V* from 10 kHz to 1.2 GHz.

True rms response to 30 mV**.

Convenient push-button ranging.

DC analog output.

High input resistance, low input capacitance.

Overload protection to 400 Vdc and 10 Vac.

VSWR less than 1.2 up to 1.2 GHz.

*To 300 V, up to 700 MHz, with accessory 100:1 divider.
**To 3 V, up to 700 MHz, with accessory 100:1 divider.

The characteristics of the instrument include: high reliability, fast warmup (1 minute typical), long intervals between calibrations, plug-in PC boards for ease in servicing or modifying, lightweight, and other advantages of solid state design.

## 1.2 Equipment Description

The instrument is basically a programmable analog instrument with linear dc output. It is available with a full range of options and accessories as described in Chapter II. Logic level programming, TTL/DTL compatible, is standard.

The instrument is sensitive, accurate, sturdily constructed, and protected against overloads. It will perform over extended periods of time without failure or need for recalibration. It is packaged as a compact bench instrument that can be easily mounted in a standard 19-inch rack using an optional rackmounting kit.

Important input and accuracy specifications are reproduced on a reference plate fastened to the exterior top cover of the instrument. Clips for holding out-of-use accessories are provided at the rear of the instrument. Calibration instructions are reproduced on the underside of the top cover of the instrument.

Standard accessories supplied with the RF Voltmeter include one each of the following:

RF Probe with low-noise cable and connector.

50-ohm BNC adapter.

Probe Tip (removable) with grounding clip lead.

### 1.2.1 Frequency Capability

The calibrated frequency range of the instrument extends from 10 kHz to 1.2 GHz, with uncalibrated response to beyond 8 GHz. Relative accuracy above 1.2 GHz is typically ±0.5 dB.

A 50-ohm BNC Adapter is supplied as a standard accessory with the instrument for 50-ohm voltage measurements up to 600 MHz. A correction curve (Figure 7A) is included for frequencies above 50 MHz. For higher-frequency measurements and for through-line voltage measurements the optional accessory Tee Adapter is recommended. It is designed to compensate for the rf probe capacitance and to present a good vswr (better than 1.2) up to 1.2 GHz. It may be used in conjunction with a 50-ohm load for terminated voltage measurements. In a coaxial line its insertion loss is low; however, a chart (Figure 7B) is supplied showing loss vs. frequency. See Figure 4 for typical vswr.

### 1.2.2 Voltage Capability

The voltmeter has eight ranges, from 1 millivolt full scale to 3 volts full scale, arranged in 1-3-10 sequence. No attenuator attachments are required for measurements up to 3 volts. While this range is ample for most rf voltage measurements, the capability of the instrument can be increased to 300 volts (up to 700 MHz) by using the optional accessory, high ß 100:1 Voltage Divider. Use of the 100:1 Voltage Divider also increases the input resistance of the supplied RF Probe by a factor greater than 100.

### 1.2.3 True RMS Response

The voltmeter provides true rms response for signal inputs below approximately 30 millivolts (below 3 volts, up to 700 MHz, with the 100:1 Voltage Divider). As the input level increases, the waveform response gradually approaches peak-to-peak, calibrated on the indicator in rms. Thus, in addition to making precise sinusoidal voltage measurements at all levels, the instrument measures non-sinusoidal or asymmetrical signals within the rms region without loss of accuracy.

### 1.2.4 Low Noise

The RF Voltmeter has been designed and constructed to hold noise from all sources to a minimum.

The probe cable is of special low-noise design; a vigorous flexing causes only momentary, minor deflections on the most sensitive range. The Probe is not sensitive to shock or vibration; even sharp tapping on the probe barrel causes no visible deflection on any range.

Amplification takes place at 94 Hz, reducing susceptibility to any 50 or 60 Hz line-frequency-related fields. A unique circuit reduces the low-level noise originating from the mechanical chopper and renders the instrument immune to changes in chopper performance that could occur with the passage of time.

### 1.2.5 Minimal Zero Adjustment

Zero adjustment is not required on the upper five sensitivity ranges of the instrument. For measurements on the lower three ranges, the Zero control is set on the most sensitive range before operation. This control balances out small thermal voltages in the probe elements and, once adjusted, requires only infrequent checking during the course of subsequent measurements.

### 1.2.6 DC Output

The voltmeter provides a linear dc output whose current capability of 1 mA into 1000 ohms is extremely stable. When used as part of an automatic test system, the fast response of the instrument's dc output to an input step function allows more tests per unit time.

For system or external requirements, all input and output connections are made at the card-edge connector on the rear of the instrument. See Figure 11 for receptacle connections.

CHAPTER II

## SPECIFICATIONS

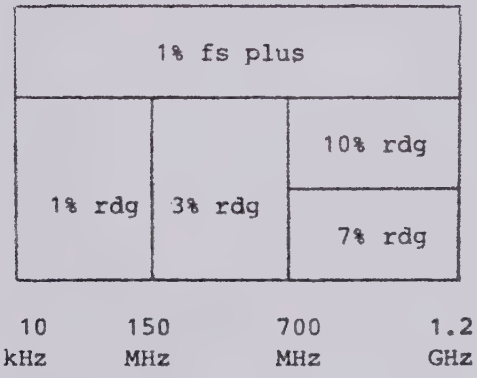
Voltage Range: 100 µV to 3 V (300 V up to 700 MHz with accessory 100:1 voltage divider). Voltage sensitivity is 100

Full Scale Voltage Range: 1, 3, 10, 30, 100, 300, 1000, and 3000 mV.

dBm Range: -60 to +23 dBm (+63 dBm up to 700 MHz with optional accessory 100:1 Voltage Divider).

Frequency Range: 10 kHz to 1.2 GHz (uncalibrated response to approximately 8 GHz).

Accuracy:




*Below 1 mV, add 1% fs.

Meter: 4-1/2 inch taut-band

Two linear voltage scales

0 to 3; 0.05 per division

0 to 10; 0.1 per division

One logarithmic dBm scale

-10 to +3; 0.2 per division max.

Meter Unrest:
(1 mV fs range only)

| Indicated Voltage | Unrest |
|---|---|
| Above 600 µV | < 1% fs |
| 300 µV to 600 µV | < 2% fs |
| 100 µV to 300 µV | < 5% fs |

Power: 115 or 230 V ±10%, 50 to 400 Hz.

RFI: There is no detectable radiated or conducted leakage from instrument or probe.

Temperature: In accordance with ANSI (ASA) Spec. 39.7.

| Temperature Range | Temperature Influence | |
|---|---|---|
| | Instrument | RF Probe |
| Ref. 21° to 25°C | 0 | 0 |
| Normal, 18°C to 30°C | 0 | ±1% rdg |
| Severe, 10°C to 40°C | ±1% rdg | ±4% rdg |

Waveform Response: True rms response for input levels up to 30 mV (3 V to 700 MHz with 100:1 Voltage Divider), with transition to peak-to-peak (calibrated in rms) at higher levels.

Crest Factor: 420 to 1.4 depending upon input level (see Table II).

Input Impedance: See Figures 1 and 2.

VSWR: Less than 1.2 to 1.2 GHz (return loss greater than 23 dB). See Figures 3 and 4.

Power Sensitivity: 200 pW, minimum detectable power in 50 ohms.

| | |
|---|---|
| DC Output: | 0 to 10 V dc proportional to rf input voltage. Source resistance of 9 kΩ; will deliver 1 mA into 1 kΩ load. Full scale input step function response time less than 100 ms on 30 mV fs to 3 V fs ranges, increasing to 1 sec. on the 1 mV fs range. |
| Dimensions: | 5.2" H (without rubber feet), 8.3" W (1/2 of standard 19 inch rack module), 11.5" D (132 x 211 x 292 mm). |
| Weight: | Net 7 lbs. (3.2 kg) |
| Accessories Furnished: | RF Probe with low-noise cable and connector assembly for measurements from 10 kHz to 1.2 GHz; see Figures 1 and 2 for input resistance and capacitance. |
| | Removable Probe Tip with grounding clip lead; for use up to approximately 100 MHz. |
| | 50 Ω BNC Adapter. Used for measurements up to 600 MHz with a 50-ohm system; for vswr see curve of Figure 3. |
| Warm-Up: | Warm-up period, typically 1 min. Adjust zero on 1 mV range when measuring below 30 mV. |
| Accessory Kit: (Optional) | Unterminated BNC Adapter. Used for coaxial connection up to approximately 100 MHz, or to 400 MHz when fed from a 50-ohm source in an electrically short system. |
| | 100:1 Voltage Divider. Attenuates input signal by a factor of 100 (±1%), permitting measurements up to 300 volts and extending the rms measuring range to 3 volts; increases input resistance by a factor of 1000; operates from 50 kHz to 700 MHz. Maximum input potential, 1000 volts, dc plus peak ac. |

| | |
|---|---|
| Accessory Kit: (Optional) (Continued) | 50 Ω Tee Adapter. Type N Tee Connector; permits connecting into 50-ohm line; required for measurements above approximately 100 MHz; for vswr see curve of Figure 4. |
| | 50 Ω Termination. Type N 50-ohm termination for use with Tee Connector. |
| Other Accessories (Optional) Available: | Special 1 kHz to 250 MHz RF Probe. Low frequency probe for measurements ranging from 1 kHz to 250 MHz; input resistance essentially the same as that of standard RF Probe. |
| | Unterminated Type N Adapter. May be used with all probes. Used for coaxial connection up to approximately 100 MHz, or to 400 MHz when fed from a 50-ohm source in an electrically short system. |
| | Single Rack Mounting Kit. Kit for mounting one voltmeter as one-half of a module in a standard 19-inch rack. |
| | Double Rack Mounting Kit. Kit for mounting two voltmeters side-by-side in a standard 19-inch rack. |

*IMPORTANT NOTE:* To fully exploit the capabilities of this instrument, the accessories listed below are required for the indicated ranges of operation.

Table 1. Required Accessories

| MEASURING RANGE | REQUIRED ACCESSORY | REMARKS |
|---|---|---|
| 100 MHz to 600 MHz | 50 Ω Adapter for shielded connection to 50 Ω line; other impedances available on request. | Supplied as standard equipment |

Table 1. Required Accessories (Continued)

| MEASURING RANGE | REQUIRED ACCESSORY | REMARKS |
|---|---|---|
| Above 600 MHz | Tee Connector and 50 Ω Termination for connection into 50 Ω line. | Available separately |
| 1 kHz to 250 kHz | Low Frequency RF Probe | Available separately |
| Input levels up to 300 V; rms response with levels to 3 V. | 100:1 Voltage Divider; operates over frequency range from 50 kHz to 700 MHz | Available separately |

Table 2. Crest Factors

| VOLTAGE RANGES (mV) AND CREST FACTORS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Voltage Ranges (mV) | 1 | 3 | 10 | 30 | 100* | 300* | 1000* | 3000* |
| Crest Factor** | 420 to 42 | 70 to 14 | 21 to 4.2 | 7 to 1.4 | 420 to 42 | 70 to 14 | 21 to 4.2 | 7 to 1.4 |

*With accessory 100:1 Voltage Divider (see Table 1).

**Maximum permissible ratio of peak to rms value of voltage.

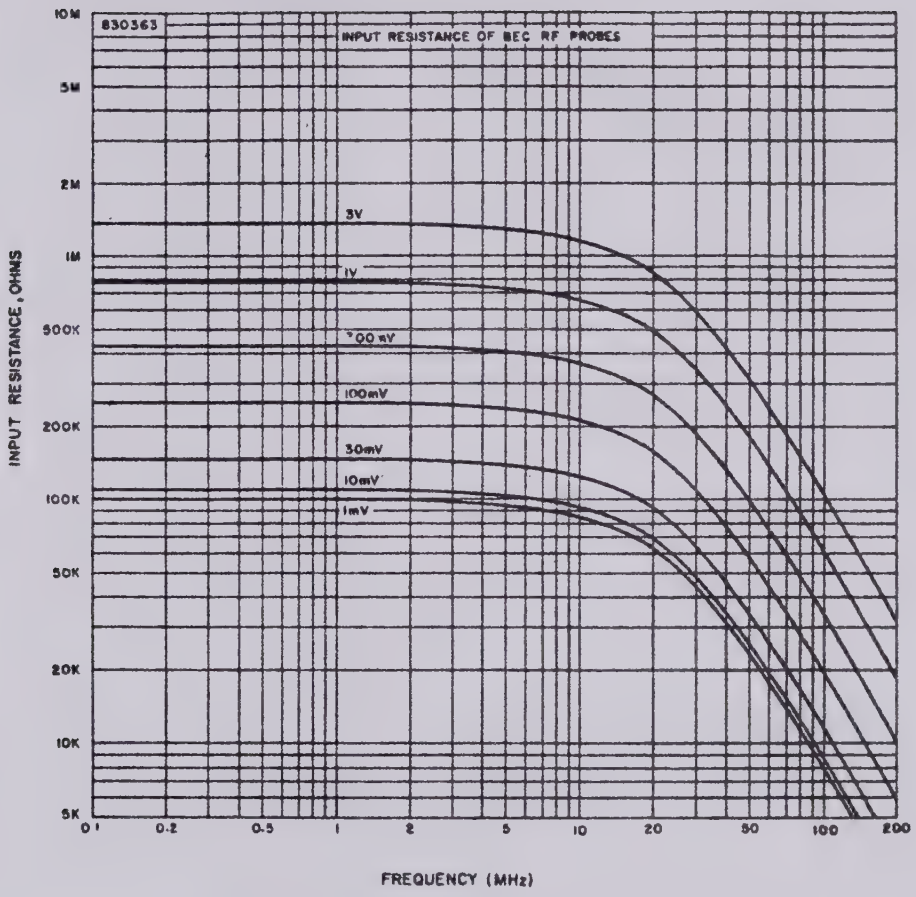
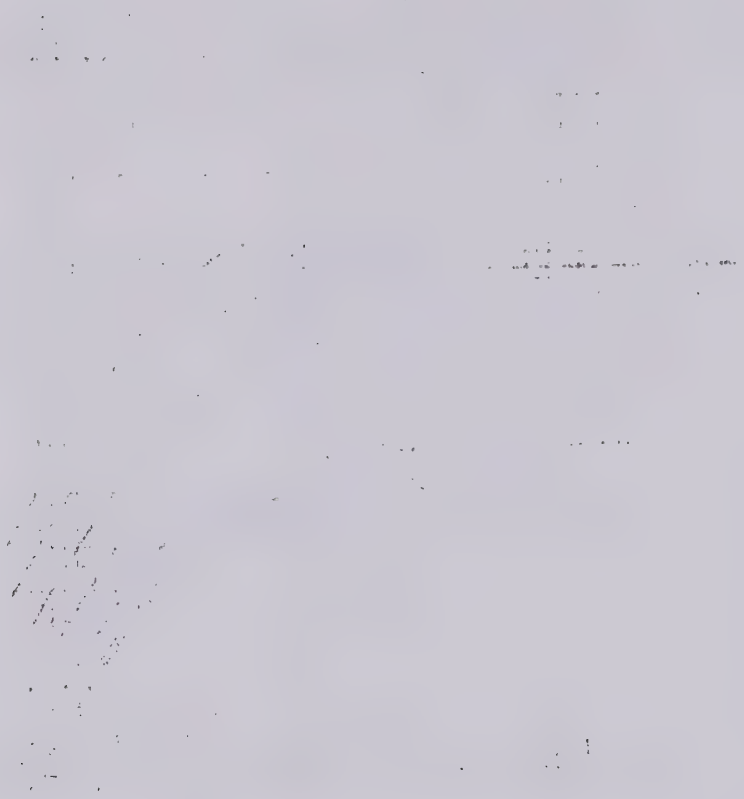



Figure 1. Input Resistance of RF Probe as a Function of Input Level and Frequency



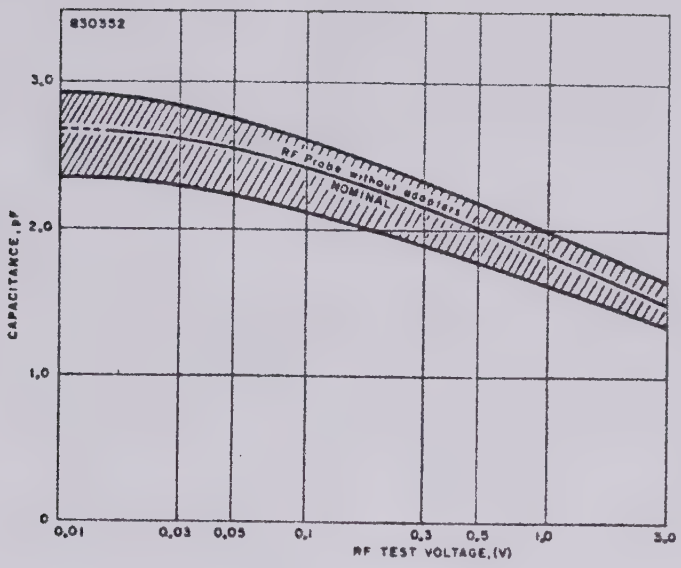



Figure 2. Input Capacitance vs Input Level of Probe (Measured at 10 MHz)

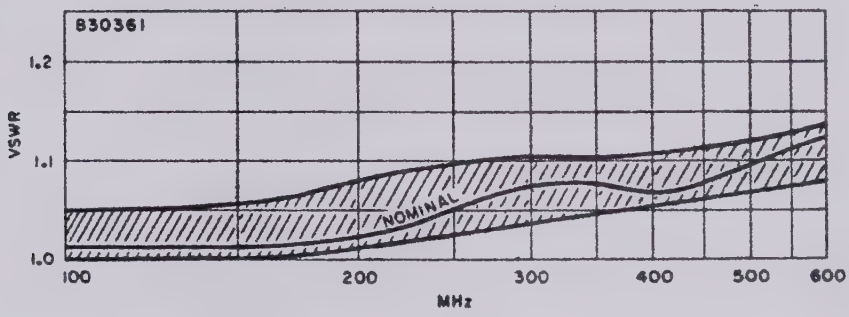



Figure 3. Typcal VSWR of RF Probe with 50 Ω BNC Adapter

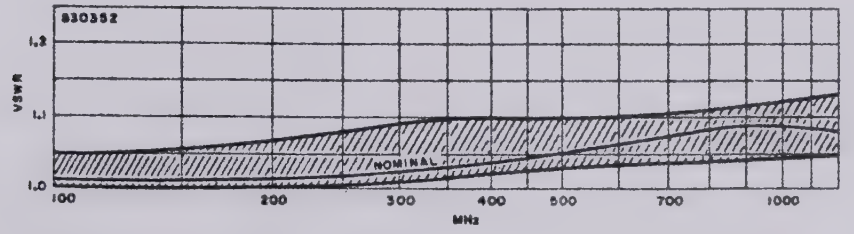



Figure 4. Typcal VSWR of RF Probe with Type N Tee Adapter and 50 Ω Termination

CHAPTER III

# OPERATION

## 3.1 Installation

The voltmeter has been inspected and tested at the factory before packing, and it is shipped ready for operation. If there is any indication of shipping damage, immediately notify the carrier before attempting to put the instrument into operation.

### 3.1.1 Operating Controls and Indicators

The controls and indicators are shown in Table 3.

Table 3. Controls and Indicators

| | |
|---|---|
| PWR ON | This switch turns on the instrument power. |
| FULL SCALE | These range pushbuttons (1, 3, 10, 30, 100, 300, 1000, and 3000 mV, and -50, -40, -30, -20, -10, 0, +10, and +20 dB) select the operating range. |
| Meter | A 4-1/2 inch taut-band meter with two linear voltage scales reading out 0 to 3 with 0.05 per division and 0 to 10 with 0.1 per division; and one logarithmic dBm scale reading out -10 to +3 with 0.2 per division maximum. |
| ZERO (Control) | This control is used to zero the instrument. |

The following items are on the rear panel:

| | |
|---|---|
| Fuse Holder and Fuse | A fuse holder is located on the rear panel for installing either a 0.10 ampere, 115 V, or a 0.06 ampere, 220 V, Bussman MDL SLO-BLO fuse. |

| | |
|---|---|
| Slide Switch | Switch which is set to 115 V or 230 V, according to the available power source. Be sure that the proper fuse is located in the fuse holder. |
| Recorder Output Terminals (Rear Panel) | A dc voltage proportional to the indicator reading is available at these terminals.<br>F. S. output = +10 V<br>Output resistance = 9 kΩ |
| Component Holders (Clips) | Three component holders or component clips are located at the rear panel for securing accessories which are not in use. |
| REMOTE CONNECTIONS (Use with an Amphenol 225-22221-103 connector or equivalent) | A card edge connector is mounted at the rear of the instrument. See Figure 10 for the pin designations. |
| (Symbol on Rear Panel) | This safety requirement symbol has been adopted by the International Electro-technical Commission, Document 66 (Central Office) 3, Paragraph 5.3, which directs that an instrument be so labeled, if, for the correct use of the instrument, it is necessary to refer to the instruction manual. In this case it is recommended that reference be made to the instruction manual when connecting the instrument to the proper power source.<br><br>Verify that the right fuse is installed for the power available and that the switch on the rear panel, "0.10 A and 0.06 A, 50-400 Hz", is set to the applicable operating voltage of 115 V or 230 V. Within a brief time, the use of this symbol will be acted upon by ANSI(ASA). |

## 3.2 Operating Procedure

In the following paragraphs, the initial operating procedure is described, as well as operating notes and recommended connection methods.

### 3.2.1 Initial Operating Procedure

a. Be sure that the serial number of the probe to be used is the same as that of the voltmeter. (Each instrument is calibrated for its particular rf probe.) Use of a probe other than that for which the instrument was calibrated may result in measurement errors.

b. Connect the probe cable to the PROBE jack on the front panel.

c. Check the setting of the power switch on the rear panel to be sure that it is set to the proper position for the line voltage available.

d. Plug the instrument's power cable into a power receptacle. Push PWR ON switch button.

e. Press the 1 mV range button; the panel meter pointer should rest on zero. If it does not, use the ZERO control to set the meter to zero. (This adjustment will hold for the other ranges.) The instrument is now ready for use. (See Paragraph 3.3.5.)

## 3.3 Operating Notes

While using the voltmeter is a direct and straight-forward process, there are certain precautions and procedures which MUST be observed to obtain satisfactory results.

### 3.3.1 Overload Limits

The RF Probe supplied with the instrument is overload-protected to 10 volts, ac, and to 400 volts, dc. *EXCEEDING THESE LIMITS MAY RESULT IN PERMANENT DAMAGE TO THE PROBE.*

The 50-ohm adapter should not be subjected to continuous overload of more than 10 volts (dc + rms ac) to avoid excessive heating of the terminating resistor.

Where voltages above these limits are likely to be encountered, the 100:1 Voltage Divider is required. Maximum rating of the Voltage Divider is 1000 volts, dc + Peak ac.

### 3,3.2 Connection for Measurements Below 100 MHz

The RF Probe supplied is equipped with a detachable tip and ground lead. For measurements of signals below approximately 100 MHz, this tip provides a convenient means for both signal and ground connection.

### 3.3.3 Connection for Measurements Above 100 MHz

For frequencies above 100 MHz, the probe tip should NOT be used. Connection should be made directly to the center contact of the probe with the ground connection kept as short as possible.

The connection recommendations outlined in Table 4 should be followed to maintain specified accuracy.

Table 4. Connection Recommendations

| FREQUENCY | SIGNAL CONNECTION |
|---|---|
| Up to 100 MHz | Probe with tip and grounding lead (supplied) |
| 100 to 250 MHz | Probe without tip or probe with 50 Ω Adapter (Supplied)<br>Probe with Tee Adapter (optional) |
| 250 to 600 MHz | Probe with 50 Ω Adapter (supplied)<br>Probe with Tee Adapter (optional) |
| 600 MHz to 1.2 GHz | Probe with Tee Adapter (See Fig. 5) (optional) |

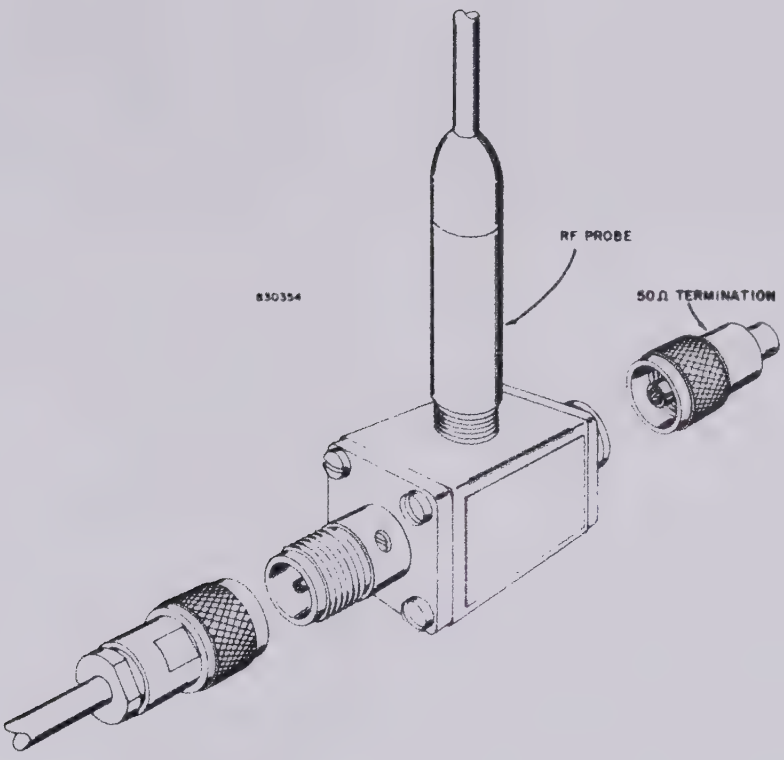



Figure 5. Assembly of Type N Tee Adapter

3.3.4 Low-Level Measurement

The voltmeter will provide reliable, reproducible measurements of signal levels as low as 100 microvolts.

Preliminary zero adjustment is essential when using the lowest range scale to achieve the specified accuracy, and it is strongly recommended for all ranges up to 30 millivolts.

3.3.5 Making the Zero Adjustment

When the instrument is to be used on the 1 mV range, the following zero adjustment procedure should be followed:

a. Set the FULL SCALE range selector to the 1 mV position.

b. Be sure that no voltage is applied to the probe, and that it is adequately shielded from local fields. This can be done by partially unscrewing the probe cap until the tip just breaks contact with the internal connector, leaving the metal shell engaged with the body threads. Alternately, the probe tip can be removed and the 50-ohm termination mounted in its place.

c. Adjust the ZERO control to bring the meter reading to zero. Noise will cause the reading to fluctuate up to ±5% of full scale. Adjust the ZERO control so that the reading averages zero.

3.3.6 Signal Overload on 1 mV Range

On the most sensitive (1 mV) range, application of a large ac signal overloads the amplifier and a short time is required for the high-impedance input circuit to discharge. This effect is significant for signals above approximately 100 millivolts. Typically, application of a 1 volt signal will require a recovery time of about thirty seconds before subsequent measurements should be made. It should be noted, however, that such overloads cause no damage to the equipment as long as they are within the limits outlined in Paragraph 3.3.1.

3.3.7 Temperature Effects

The accuracy specifications apply over temperatures from 50°F to 104°F. Outside of these limits operation of the equipment is possible but appreciable inaccuracies can be expected. However, no permanent change in probe characteristics will result from any reasonable high or low temperature exposure.

It should be noted that inaccuracies of measurement resulting from temperature effects may occur shortly after soldering to the probe tip, or measuring with the probe in the vicinity of heat sources such as resistors, heat sinks, vacuum tubes, and so forth.

When making low-level measurements (below approximately 2 millivolts) it is important to make sure that the probe has attained a uniform temperature throughout its body. A temperature gradient between the inside and outside of the probe can generate a small thermal voltage that may add to the dc output of the detector diodes.

### 3.3.8 Hum, Noise, and Spurious Pick-up

When measuring low-level signals precautions should always be taken to avoid the possibility of errors of measurement resulting from hum, noise, or stray rf pick-up. Although all low-frequency hum and noise are attenuated at the input, it is still possible for unwanted high-level signals to cause errors. In some cases it may be necessary to provide extra shielding around the probe connections to reduce stray pick-up. Typical sources of spurious radiation are: induction or dielectric heating units, diathermy machines, local radio transmitters and grid dip meters.

## 3.4 DC Output

The dc output provided at the rear panel binding posts is a linear function (typically within 1%) of the input level, as long as the input signal is greater than 20% of full scale. For inputs less than 20% of full scale the output is NOT linear, but may be corrected by referring to Paragraph 3.6 and Figure 6. Polarity of the dc output is positive with respect to the instrument ground, the negative dc output terminal being at ground potential. Output resistance is 9 kΩ.

## 3.5 Low Frequency Measurements

The RF Probe supplied with the instrument provides measurements within the specified accuracy from 10 kHz to 1.2 GHz. For measurements at lower frequencies a Low Frequency RF Probe is available. It operates over a frequency range from 1 kHz to 250 MHz.

*Important Note:* After installing the Low Frequency RF Probe, the instrument *must* be checked for accuracy of calibration, and recalibrated if required (see paragraphs 5.3 and 5.4).

## 3.6 Correction Curves for Actual Voltage vs Meter Reading

Use the curves of Figure 6 to correct for non-linearity below 20% of full scale on each range.

### 3.7 Loss vs Frequency Correction for 50 Ω BNC Adapter

Use the curve of Figure 7a to make corrections for high-frequency roll-off when using the 50 Ω BNC Adapter.

### 3.8 Loss vs Frequency Correction Curve for Tee Adapter

Use the curve of Figure 7b to make corrections for transmission loss when using the Type N Tee Adapter.

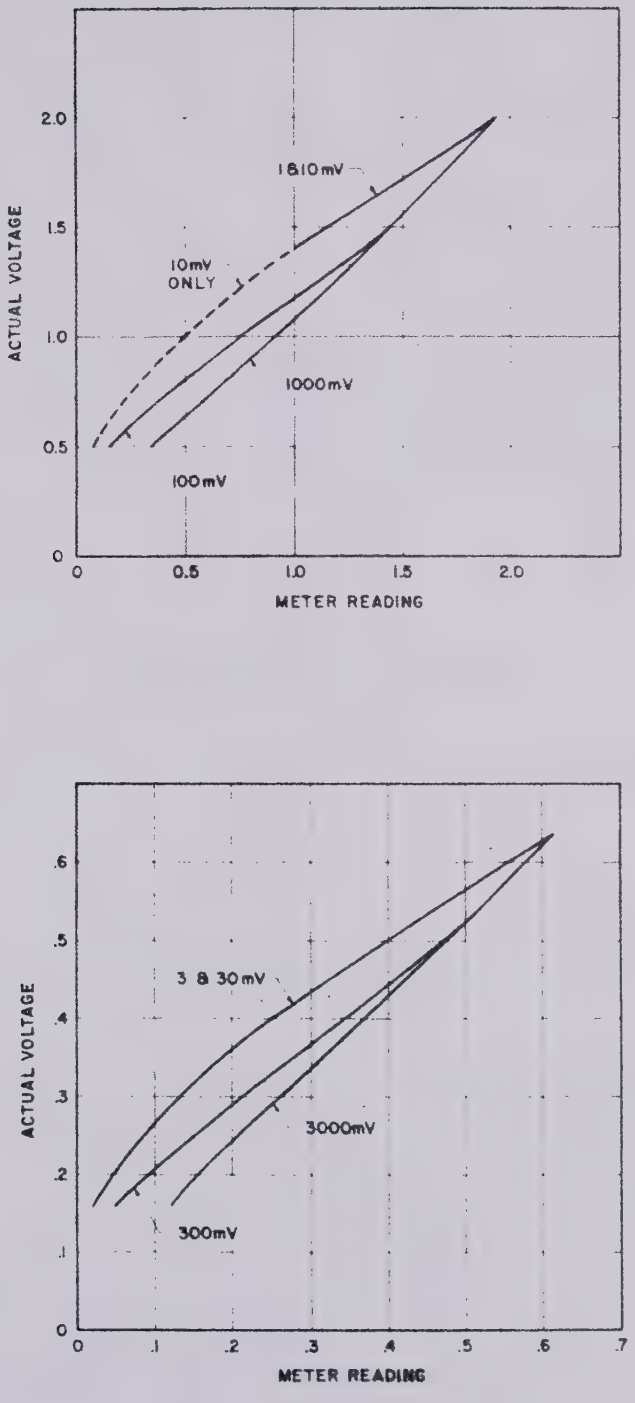
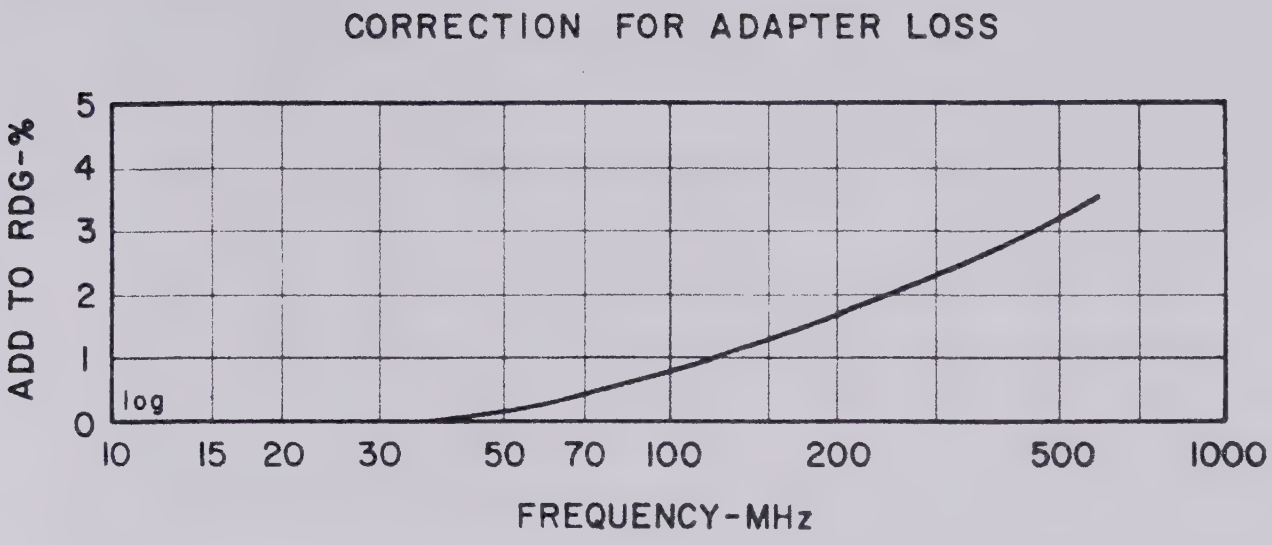



Figure 6. Correction Curves, Actual Voltage vs Meter Reading




EXAMPLE:
AT 250MHz, METER READS 50mV.
ADD 2%. TRUE VOLTAGE IS 51mV.

Figure 7A. 50 Ω BNC Adapter Correction Curve

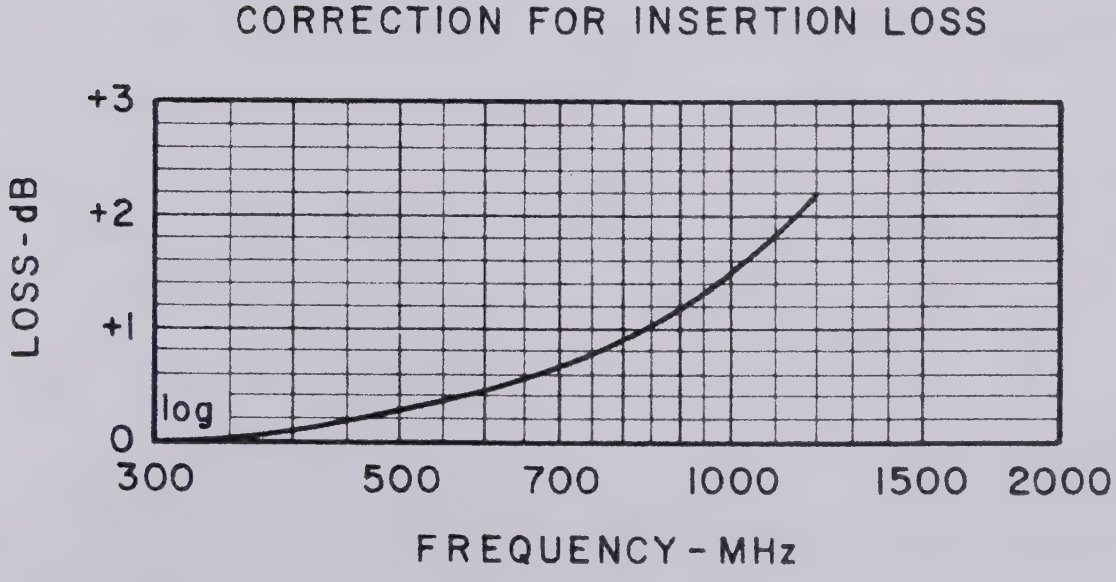



Figure 7B. Type N Tee Adapter Correction Curve

CHAPTER IV

# THEORY OF OPERATION

## 4.1 General

The operating principles of the voltmeter are shown in the following block diagram (Figure 8). The essential elements of the instrument are the probe, chopper driver, chopper, attenuator, preamplifier, amplifier, pulse generator, sync detector, shaping amplifier, panel meter, and power supply.

### 4.1.1 RF Probe

The RF Probe embodies a full-wave diode detector which rectifies the signal under study to a dc voltage whose level is a function of the input level. While operating in the square-law region (below approximately 30 millivolts) the detector provides true rms response. As the input level increases beyond 30 millivolts, waveform response gradually approaches peak-to-peak, calibrated on the scale in rms.

In addition to increasing efficiency, use of a full-wave rectification in the detector probe permits measurement of signals having highly asymmetrical waveforms without errors stemming from turn-over effect.

The diodes used in the RF Probe have been carefully selected for specific characteristics. The user is urged NOT to attempt their replacement with any off-the-shelf types.

### 4.1.2 Attenuator and Amplifiers

The dc output of the probe is converted to ac by the mechanical chopper. The resultant ac signal is applied to the attenuator and amplifier sections. For each range the output voltage from the 2nd amplifier is approximately 3 V peak-to-

peak. It is accomplished by ranging both the attenuation and the gain of the second amplifier in the following manner:

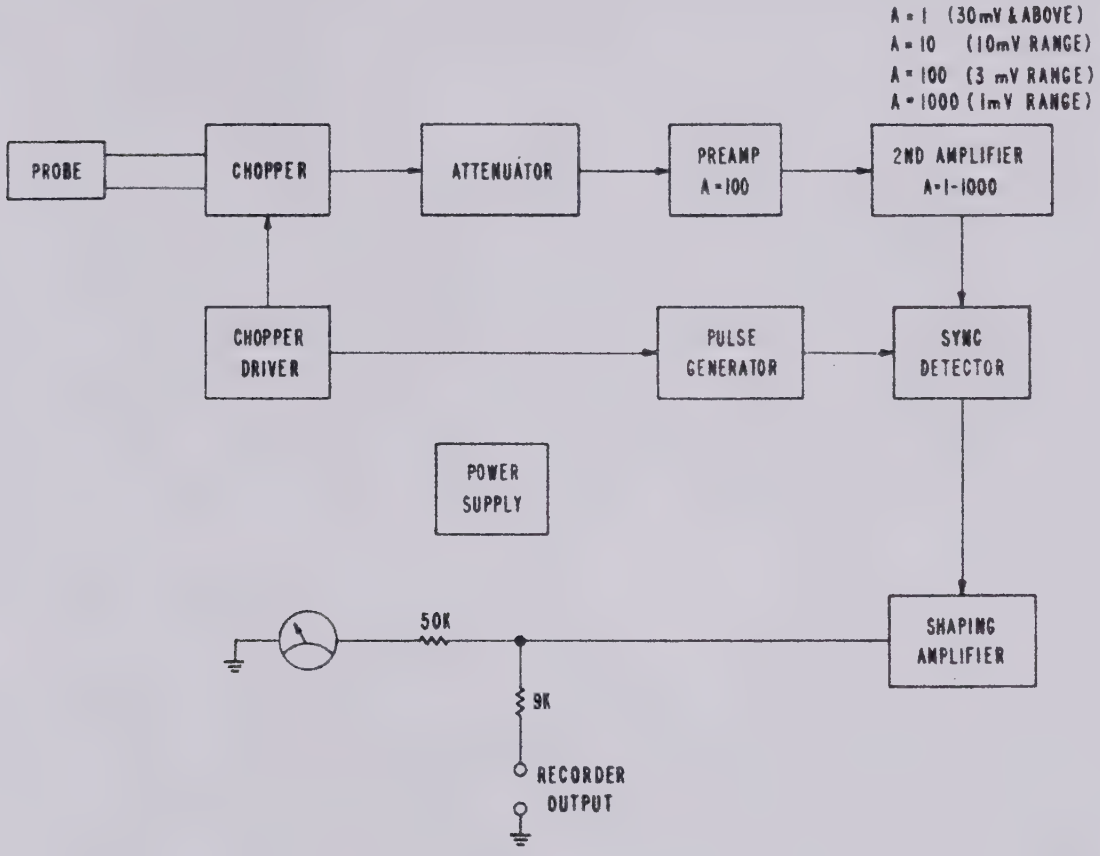



Figure 8. Block Diagram

| RANGE | $\frac{1}{\text{ATTN}}$ | GAIN 2nd AMP |
|---|---|---|
| 1 | 1 | 1000 |
| 3 | 1 | 100 |
| 10 | 1 | 10 |
| 30 | 1 | 1 |
| 100 | 0.15 | 1 |
| 300 | 0.04 | 1 |
| 1000 | 0.01 | 1 |
| 3000 | 0.004 | 1 |

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The preamplifier has a constant gain of X100, and is designed for very low input noise. Both amplifiers have moderately wide bandwidths and are stabilized by large amounts of negative feedback.

### 4.1.3 Synchronous Detector

The amplified ac signal from the second amplifier is converted to dc by the synchronous detector. The peak-to-peak amplitude is derived from a shunt-series capacitor storage circuit using JFET switches. The synchronous detector is driven by pulses in the chopper-driver circuit, thus assuring exact synchronization. The characteristics of the detector determine the effective bandwidth of the amplifier-detector combination and allow modification of the bandwidth for different range conditions. The detector also provides conversion without offset, with excellent linearity.

### 4.1.4 Shaping Amplifier

The conversion of rf to dc in the probe is non-linear, the response being virtually square-law for the lowest ranges and gradually becoming quasi-linear for the 3 V range. The shaping amplifier converts the non-linear output of the phase detector to a linear output by using a segmental approximation to the exact correction. The shaping amplifier is actually an operational amplifier so connected that, as the signal increases at its output, its gain is reduced by successively paralleling resistors across the feedback resistors. The number of segments required to adequately linearize the response varies from 6 for the "square-law" ranges down to 2 for the 3 V range. The output of the shaping amplifier is +10 V which drives the panel meter and is applied to the recorder terminals through a 9 kΩ resistor.

### 4.1.5 Chopper-Driver Circuits

The chopper-driver block provides all of the drive signals required by the instrument. The chopper frequency is obtained by dividing the output of a unijunction oscillator by two. The oscillator also generates the switching pulse for the synchronous detector. Diode gating feeds the pulse to the proper

JFET depending upon chopper phase. The chopper frequency is normally adjusted to 94 Hz, but can be changed as much as ±10 Hz to avoid beating with harmonically related ground signals.

### 4.1.6 Power Supply

The power supply converts the ac input power to regulated +15 V and -15 V outputs. Each supply is protected by current limiting against accidental short circuits. Both supplies are adjustable to 15.0 ± 0.1 V.

### 4.1.7 Programming

The instrument is organized around an eight-line ranging system. In each functional subcircuit the switching is accomplished by solid-state devices, generally JFET's, which are actuated by the appropriate range line. The front panel range switch simply connects to the eight range lines to allow range selection. The range lines are buffered by a logic level converter. The instrument may be externally ranged by a logic "0" command on the appropriate range line and manual disable line. (It is recommended that an Amphenol connector, or equivalent, be used for remote programming connection.)

CHAPTER V

# MAINTENANCE

*NOTE:* The values and tolerances shown in this section are not specifications but are provided only as guides to the maintenance and calibration of this instrument.

## 5.1 Periodic Calibration

The voltmeter is designed to provide trouble-free operation over extended periods of time. However, as with any precision instrument, the instrument should be checked periodically to verify proper calibration. To make such calibration checks, the following equipment is required:

a. A reliable signal source of 200 kHz to 500 kHz with less than 1% distortion at levels up to 3 volts across 50 ohms.

b. A precision voltmeter such as the Ballantine Model 310A or 300H, the Boonton Electronics Model 93A or 93AD, or the Hewlett-Packard Model 400D or 400H or equivalent.

c. A precision dc voltmeter capable of measuring ±15.0 V with an accuracy of 0.25%.

d. Frequency counter such as Data Precision Model 245.

## 5.2 Precautions When Checking Calibration

When checking the calibration of an instrument having the sensitivity and bandwidth of this voltmeter, it is essential to take precautions against errors

resulting from stray pick-up voltages. (See Paragraph 3.3.8.) A well-shielded signal source must be used in conjunction with coaxial connections to both the voltmeter and the standard reference meter. Even with a well-shielded generator and connections, it is sometimes possible for the reference meter to pick up stray rf signals and feed them into the probe. It is advisable to test for this condition by disconnecting the standard meter and noting any change in level.

## 5.3 Calibration Check

Using the equipment listed in Paragraph 5.1, check the calibration of each range using a test voltage equal to the full scale value. If the check reveals that recalibration is required, the procedure outlined in Paragraph 5.4 should be followed.

## 5.4 Calibration Procedure

The voltmeter should be calibrated at room temperature (74°F) after a minimum warm-up time of five minutes.

A calibration outline is provided inside the top cover of the instrument (see Figure 9). The adjustment references listed below are the same as those recorded on the top cover.

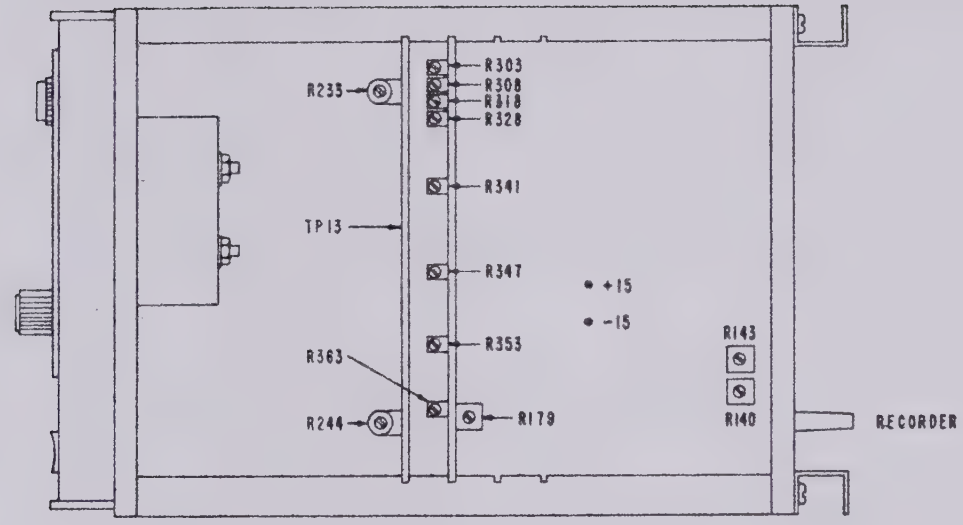
Adjustment No. 1. Measure the -15.0 V supply voltage at the -15 V Test Point located on the Main Amplifier board at C119. Adjust R143 to 15.0 ± 0.1 V.

Adjustment No. 2. Measure the +15.0 V supply voltage at the +15 V Test Point located on the Main Amplifier board at C118. Adjust R140 for a reading of +15.0 ± 0.1 V.

Adjustment No. 3. Set the FULL SCALE range selector to the 1000 mV range, apply 1000 mV input and measure the chopper frequency at Test Point 13, located on the Chopper-Driver board. Adjust R244 for a frequency of 94 ± 1 Hz (10.64) JD 7-13-94 (106.4 mS). In some cases it may be desirable to offset the chopper frequency to avoid beating with a harmonic of the power line frequency. Any frequency within the adjustment range will not degrade the performance of the instrument.



CAUTION
CHANGES HAVE BEEN MADE
ON THIS PAGE.
SEE ISSUE SHEET.
Type Error JD 7-13-94




• TEST POINT
† REPEAT STEP #4

| ADJ NO | CONT | FUNCTION | RANGE | INPUT ±0.2% | ADJUST |
|---|---|---|---|---|---|
| 1 | R143 | -15 V ADJ | — | 0 | -15.0V ±0.1V AT -15V TP |
| 2 | R140 | +15 V ADJ | — | 0 | +15.0V ±0.1V AT +15V TP |
| 3 | R244 | CHOPPER FREQUENCY | 1000 mV | 1000 mV | 94±1Hz AT TP 13 |
| 4 | R401 | FRONT PANEL ZERO | 1 mV | 0 | AVERAGE ZERO INDICATION |
| 5 | R233 | DC ZERO | 30 mV | 0 | ZERO INDICATION |
| 6 | R353 | RANGE ADJ | 1000 mV | 1000 mV | +10.00V AT RECORDER TERMINALS DC VOLTMETER INPUT > 10 M OHMS |
| 7 | R179 | METER FS ADJ | 1000 mV | 1000 mV | 1000 mV INDICATION |
| 8 | R363 | RANGE ADJ | 3000 mV | 3000 mV | 3000 mV INDICATION |
| 9 † | R303 | RANGE ADJ | 1 mV | 1 mV | 1.000 mV INDICATION |
| 10† | R308 | RANGE ADJ | 3 mV | 3 mV | 3.000 mV INDICATION |
| 11† | R318 | RANGE ADJ | 10 mV | 10 mV | 10.00 mV INDICATION |
| 12 | R328 | RANGE ADJ | 30 mV | 30 mV | 30.00 mV INDICATION |
| 13 | R341 | RANGE ADJ | 100 mV | 100 mV | 100.0 mV INDICATION |
| 14 | R347 | RANGE ADJ | 300 mV | 300 mV | 300.0 mV INDICATION |

Figure 9. Calibration Instructions

Adjustment No. 4. Set the FULL SCALE range selector to the 1 mV range and zero the instrument as described in Paragraph 3.3.5.

Adjustment No. 5. Set the FULL SCALE range selector to the 30 mV range and adjust R233 for a zero reading of the RECORDER terminals on the back panel.

Adjustment No. 6. Set the FULL SCALE range selector to the 1000 mV range and apply 1000 mV input; adjust R353 for +10.00 V at the RECORDER terminals.

Adjustment No. 7. Set the FULL SCALE range selector to the 1000 mV range and apply 1000 mV input; adjust R179 for a 1000 mV indication.

Adjustment No. 8. Set the FULL SCALE range selector to the 3000 mV range and apply 3000 mV input; adjust R363 for a 3000 mV indication.

Adjustment No. 9. Set the FULL SCALE range selector to the 1 mV range (zero the instrument as in Adjustment No. 4), apply 1.000 mV input, and adjust R303 for a reading of 1.000 mV.

Adjustment No. 10. Set the FULL SCALE range selector to the 3 mV range (zero as in Adjustment No. 4), apply 3.000 mV input, and adjust R308 for a reading of 3.000 mV.

Adjustment No. 11. Set the FULL SCALE range selector to the 10 mV range (zero as in Adjustment No. 4), apply 10.00 mV, and adjust R318 for a reading of 10.00 mV.

Adjustment No. 12. Set the FULL SCALE range selector to the 30 mV range, apply 30.00 mV input, and adjust R328 for a reading of 30.00 mV.

Adjustment No. 13. Set the FULL SCALE range selector to the 100 mV range, apply 100.0 mV input, and adjust R341 for a reading of 100.0 mV.

Adjustment No. 14. Set the FULL SCALE range selector to the 300 mV range, apply 300.0 mV input, and adjust R347 for an indication of 300.0 mV.

## 5.5 Troubleshooting Procedure

The following troubleshooting procedures describe the instrument's cover removal, chopper replacement and voltage and resistance tests.

### 5.5.1 Cover Removal

The cover of the instrument may be removed from the case by removing the screw on the top of the case.

### 5.5.2 Chopper Replacement

If unsatisfactory operation develops, a replacement chopper should be tried. If the new chopper does not clear the difficulty, place the original chopper back in the socket. The calibration accuracy should be rechecked after replacement.

### 5.5.3 Voltage and Resistance Tests

After determining that the trouble cannot be cured by replacement of the chopper (as noted above) it is advisable to make a systematic check of the ac voltage, dc voltage, and resistance. Once the trouble has been found and corrected, the calibration must be rechecked and readjusted as outlined in Paragraphs 5.3 and 5.4.

### 5.5.4 Test Points

Test points, waveforms, and related test voltages are shown in the schematics.

### 5.5.5 Replacement of RF Probes

The serial number of the instrument matches that of the RF Probe with which it was calibrated at the factory. If it is necessary to change probes for any reason, the instrument's calibration MUST be rechecked. In most cases, full recalibration (see procedure in Paragraph 5.4) will be required. Similarly, if the RF Probe supplied with the instrument is exchanged for a Low Frequency Probe, recalibration will be required. (See Paragraph 3.5.)

5.5.6 Probe Tests

The probe assemblies furnished with the voltmeter can be checked for vswr and frequency response by following the procedures detailed in the paragraphs below.

Should a probe exhibit out-of-tolerance performance in these tests, the user is urged not to attempt repair himself but to send it back to the factory for repair or adjustment.

A. VSWR

(1) Test Equipment

a. Generator for the desired frequency range. Suggested signal sources are:
125 kHz - 175 MHz, Boonton Model 103A or 103B
450 kHz - 520 MHz, Boonton Model 102C or 102D
10 MHz - 1400 MHz, Wavetek Model 2001

b. Slotted line: GR Type 900 LB

c. Detector: GR Type 1241, or Boonton RF Millivoltmeter, 92B or 92C

(2) Test Procedure

a. Connect the slotted line to a proper signal source, and terminate the line with the device to be tested, i.e., the Tee Adapter and the 50 Ω Termination, or the 50 Ω Adapter.

It is necessary that the probe and RF Millivoltmeter be connected to whichever accessory is being tested. The probe supplies a perturbation for which the accessory was designed, and which it needs, to meet its specification, and the millivoltmeter permits the test level to be set to the desired value.

b. Move the carriage of the slotted line to a point of minimum voltage, then to a point of maximum voltage, and record the values.

c. The vswr is the ratio of the maximum and minimum voltages. The measurement can be repeated at other frequencies and levels, as required.

B. Frequency Response

The most accurate method of measuring the frequency response of the RF Probe for the RF Millivoltmeter is through the use of micropotentiometers, electrothermic ac-dc transfer instruments, and A-T (attenuator-thermoelement) voltmeters. Users who have these instruments available will be familiar with their application.

A method of suitable accuracy, compatible with the accuracy of the Model S-1339A, uses a point by point frequency scan in conjunction with a power divider and calibrated power meter. The method is detailed in the following paragraphs.

(1) Test Equipment

a. Signal source for the frequency range of 10 to 1200 MHz. Suggested instrument is Wavetek Model 2001, 10 - 1400 MHz. In this application the generator is manually swept.

b. Power Divider: Weinschel Model 1506A

c. Calibrated RF Power Meter: Boonton Model 42B/BD, or H-P Model 435A

(2) Test Procedure

a. Connect the equipment as shown in the Frequency Response Test Setup figure.

b. Set the frequency of the generator to 10 MHz, and adjust the output control for the desired test level. If the response is to be measured at one level only, a test voltage of 100 or 200 mV is recommended.

c. Disable the output of the generator momentarily and zero the power meter. Re-establish the output level and note the reading on the

power meter. Record the frequency of the generator and the reading of the RF Millivoltmeter. Change the frequency, in whatever increments are desired, through the range of 10 to 1200 MHz, holding the reference reading on the power meter constant.

d. Reverse the output ports of the power divider and repeat Step c.

e. The correct voltmeter reading is obtained at each frequency by averaging the two readings. This virtually eliminates the influence of frequency differences of the two ports of the power divider.

f. Further refinements can be made by filtering the output of the generator, and measuring the complex reflection coefficients of the power meter, rf millivoltmeter accessory under test, and all ports of the power divider. The usual corrections can then be made. These procedures are not usually necessary and should be done only if the additional accuracy is warranted.

C. Frequency Response and VSWR

An alternate method of measuring both the frequency response and the vswr (in terms of the reflection coefficient), but with somewhat reduced accuracy, employs a sweep generator, vswr bridge, external levelling of the generator, power divider, and sensitive oscilloscope.

(1) Test Equipment

a. Sweep Generator: Wavetek Model 2001, 10 - 1400 MHz

b. SWR Autotester: Wiltron Model 63N50

c. Oscilloscope: Tektronix Model 5100, with two 5A20 Vertical Amplifiers

d. Power Divider: Weinschel Model 1506

e. Standard 1.2:1 Mismatch Termination: Weinschel Model M1410-1.2

(2) Test Procedure

a. Connect the equipment as shown in the Swept Frequency Response Test Setup figure, and temporarily connect the probe under test to the RF Millivoltmeter. Adjust the output control of the sweep generator for a reading on the S-1339A of 100 mV at a fixed frequency of 100 MHz.

b. Calibrate one of the vertical input amplifiers of the oscilloscope for a sensitivity of 100 μV/div. The other vertical amplifier should be calibrated so that a change from 100 mV to 90 mV applied to the input of the probe under test will produce a vertical deflection of one division. This can be done easily if a Boonton Model 26A RF Millivoltmeter Calibrator is available. The probe should be temporarily connected to the output of the calibrator while output levels of 100 mV and 90 mV are alternately selected, and the sensitivity of the second input amplifier is adjusted for a deflection of one division.

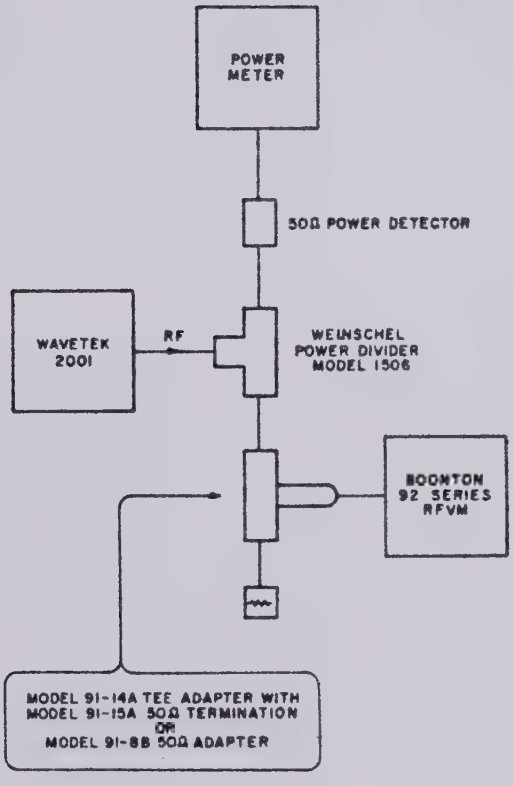
c. Substitute the Standard 1.2:1 Mismatch Termination for the accessory under test, and calibrate the graticule of the oscilloscope for a vswr of 1.2. Replace the accessory and probe.

d. Adjust the limits on the three bands of the sweep generator for coverage from 10 to 1200 MHz. Study the traces for both frequency response and vswr (return loss).

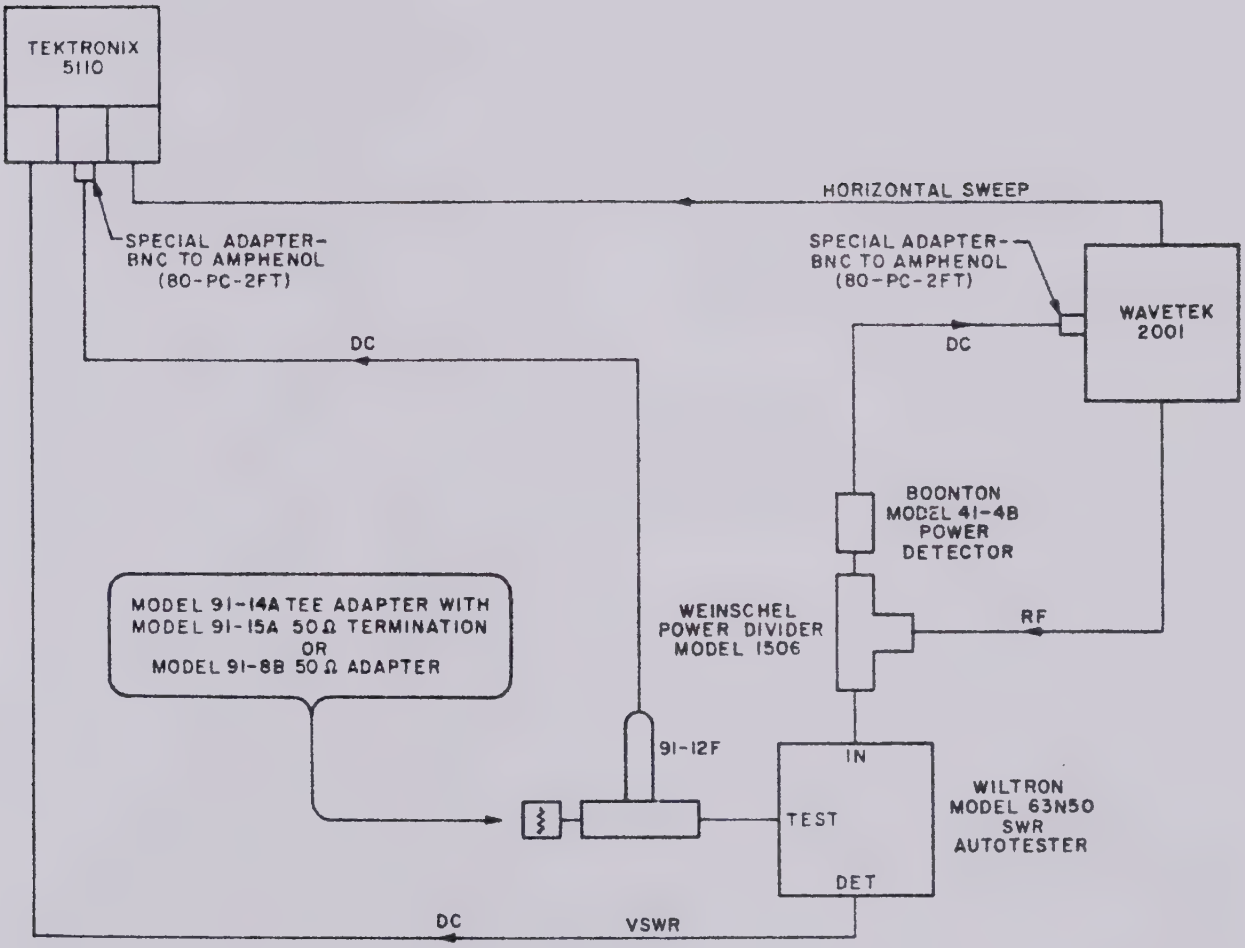
e. Reverse the output ports of the power divider and repeat Steps c and d.

f. It should be noted that the permissible error for the frequency response trace expands with frequency. For the most meaningful results, the graticule should be marked with a grease pencil, showing the maximum permissible errors for the various frequency bands, as determined with a calibrated signal of, say, 1 MHz, and at levels above and below the selected test level. It is important to note that the recovered dc from the rf probe, which is applied to the second vertical

amplifier, will vary as the square of the rf input level for test levels of 30 mV, or less. Above 30 mV the rf to dc conversion gradually changes from square law to linear, and approaches a peak-to-peak rectifier at an input of 3 volts.


POWER METER
50Ω POWER DETECTOR
WAVETEK 2001
RF
WEINSCHEL POWER DIVIDER MODEL 1506
BOONTON 92 SERIES RFVM
MODEL 91-14A TEE ADAPTER WITH MODEL 91-15A 50Ω TERMINATION OR MODEL 91-8B 50Ω ADAPTER

Frequency Response Test Setup




Swept Frequency Response Test Setup

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# CHAPTER VI

# INTERFACE

## PROGRAMMING INPUTS AND DATA OUTPUT

| Pin No. | Function | Comment | Command | Unit Loading |
|---|---|---|---|---|
| 7 | Man. disable | Disables front panel range selection | 0 | 0.1 |
| 16 | 1mV range | Selects range provided manual disable has also been selected; selecting more than one range will result in incorrect indications. Range lines must be deselected for manual operation. | 0 | 0.1 |
| 15 | 3mV " | | 0 | 0.1 |
| 14 | 10mV " | | 0 | 0.1 |
| 13 | 30mV " | | 0 | 0.1 |
| 12 | 100mV " | | 0 | 0.1 |
| 11 | 300mV " | | 0 | 0.1 |
| 10 | 1 V " | | 0 | 0.1 |
| 9 | 3 V " | | 0 | 0.1 |
| 5 | Common | Power line ground at rear panel | N/A | N/A |
| 4 | DC Analog | +10V for full scale of "1" ranges<br>+9.5V for "3" ranges | N/A | N/A |

Figure 10. Pin Designations

## 6.1 Input Characteristics

| TTL Series | Logic Level | Voltage Level | Current per Unit Load |
|---|---|---|---|
| Standard Power 54/74 | 0 | ±0.7 V | -1.6 mA* |
| | 1 | +2.4 to +5.25 V | 40 µA |

*The "-" current indicates current out of the input (external command device must sink this current). A standard power (Series 54/74) TTL output will sink and source 10 unit loads.

## 6.2 Input Pull-Up

All input terminals have internal pull-up. The current sourced by this pull-up when the input is brought to a logic level 0 is included in the loading shown in the "Unit Loading" column of the chart.

## 6.3 Analog Output

Source resistance is = 9 kΩ.

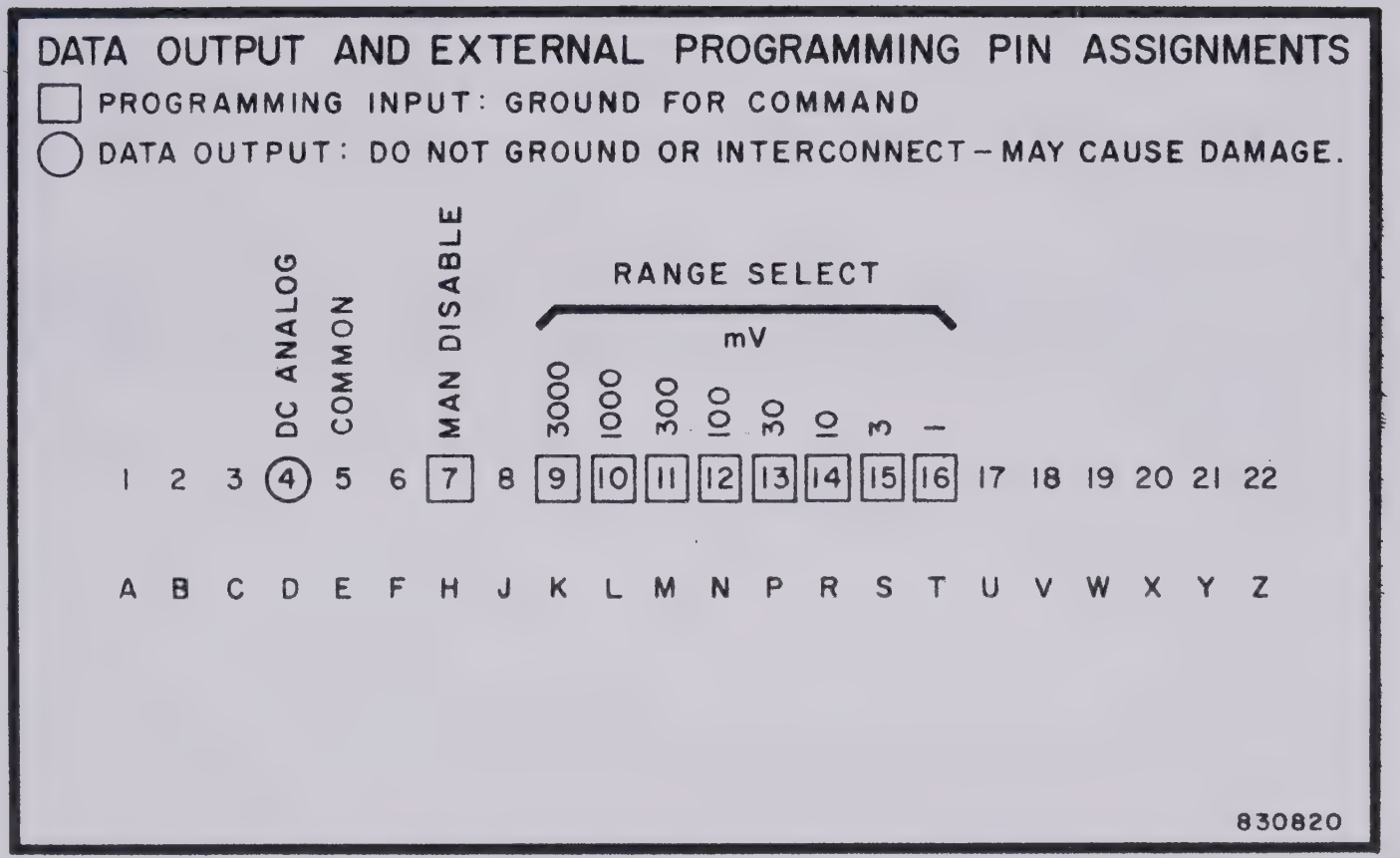
DATA OUTPUT AND EXTERNAL PROGRAMMING PIN ASSIGNMENTS
PROGRAMMING INPUT: GROUND FOR COMMAND
DATA OUTPUT: DO NOT GROUND OR INTERCONNECT – MAY CAUSE DAMAGE.
DC ANALOG COMMON
MAN DISABLE
RANGE SELECT
mV
3000
1000
300
100
30
10
3
–
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
A B C D E F H J K L M N P R S T U V W X Y Z
830820

Figure 11. External Connections

## TABLE OF REPLACEABLE PARTS

| Reference | | Description | Part No. |
|---|---|---|---|
| | | AMPLIFIER PC BOARD | |
| C101 | Capacitor, PE | 100 nF ±10% 200 V | 234005 |
| C102 | Capacitor, Elec. | 10 µF ±20% 20 V | 283205 |
| C103 | Capacitor, Mica | 100 pF ±5% 500 V | 200001 |
| C104 | Capacitor, Elec. | 10 µF ±20% 20 V | 283205 |
| C105 | Capacitor, Elec. | 33 µF ±20% 15 V | 283206 |
| C106 | Capacitor, Elec. | 10 µF ±20% 20 V | 283205 |
| C107 | Capacitor, Met. | 1.0 µF ±20% 100 V | 236007 |
| C108 | Capacitor, Elec. | 1.0 µF ±20% 35 V | 283199 |
| C109 | Capacitor, Elec. | 50 µF +75% -10% 25 V | 283159 |
| C110 | Capacitor, Elec. | 50 µF +75% -10% 25 V | 283159 |
| C111 | Capacitor, PE | 100 nF ±10% 200 V | 234005 |
| C112 | Capacitor, Elec. | 250 µF 40 V | 283207 |
| C113 | Capacitor, Elec. | 250 µF 40 V | 283207 |
| C114 | Not Used | | |
| C115 | Capacitor, Cer. | 0.001 µF GMV 500 V | 224114 |
| C116 | Capacitor, Cer. | 0.001 µF GMV 500 V | 224114 |
| C117 | Not Used | | |
| C118 | Capacitor, Elec. | 100 µF +75% -10% 25 V | 283105 |
| C119 | Capacitor, Elec. | 100 µF +75% -10% 25 V | 283105 |
| CR101 | Diode, Sig. | FDH-300 | 530052 |
| CR102 | Diode, Sig. | 1N914 | 530058 |
| CR103 | Diode, Sig. | 1N914 | 530058 |
| CR104 | Diode, Zener | 1N5243B (13 V) | 530101 |
| CR105 | Diode, Zener | 1N5235B (6.8 V) | 530089 |
| CR106 through CR110 | Diode, Sig. | 1N914 | 530058 |
| CR111 | Bridge, Rectifier | KBP-02 | 532013 |
| CR112 | Bridge, Rectifier | KBP-02 | 532013 |
| CR113 | Not Used | | |
| CR114 | Not Used | | |
| CR115 | Diode, Sig. | 1N914 | 530058 |
| CR116 | Not Used | | |
| CR117 through CR124 | Diode, Sig. | 1N914 | 530058 |
| IC101 | Voltage Regulator | µA7805 | 535011 |
| IC102 | Voltage Regulator | µA7805 | 535011 |
| IC103 | Not Used | | |
| IC104 | Voltage Regulator | LM723CN | 535037 |
| IC105 | Voltage Regulator | LM723CN | 535037 |
| J101 | Connector P/C | Amphenol 143-022-03 (22 Pin) | 479231 |
| J102 | Connector P/C | Amphenol 143-922-03 (22 Pin) | 479231 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | AMPLIFIER PC BOARD (CONTINUED) | | |
| Q101 | Transistor, FET | 2N5949 | 528019 |
| Q102 | Transistor, FET | 2N5949 | 528019 |
| Q103 | Not Used | | |
| Q104 | Transistor, FET | 2N5949 | 528019 |
| Q105 | Transistor, FET | TIS58 | 528038 |
| Q106 | Transistor, FET | HDGP 1000 | 528066 |
| Q107 | Transistor, FET | HDGP 1000 | 528066 |
| Q108 | Transistor, FET | 2N5949 | 528019 |
| Q109 | Transistor, FET | Selected | 528044 |
| Q110 | Transistor, NPN | 2N5088 | 528047 |
| Q111 | Transistor, PNP | 2N5087 | 528042 |
| Q112 | Transistor, PNP | MPSA66 | 528048 |
| Q113 | Transistor, PNP | 2N5087 | 528042 |
| Q114 | Transistor, NPN | 2N5088 | 528047 |
| Q115 | Transistor, FET | TIS58 | 528038 |
| Q116 | Transistor, FET | TIS58 | 528038 |
| Q117 | Transistor, FET | TIS58 | 528038 |
| Q118 | Transistor, FET | 2N5949 | 528019 |
| Q119 | Transistor, FET | 2N5949 | 528019 |
| Q120 | Transistor, FET | 2N5949 | 528019 |
| Q121 | Transistor, PNP | MPSA66 | 528048 |
| Q122 | Transistor, PNP | MPS6516 | 528037 |
| Q123 | Not Used | | |
| Q124 through Q131 | Transistor, PNP | MPS6516 | 528037 |
| R101 | Resistor, Comp. | 1 MΩ 5% | 343600 |
| R102 | Resistor, Comp. | 6.2 kΩ 5% | 343376 |
| R103 | Resistor, Comp. | 6.2 kΩ 5% | 343376 |
| R104 | Resistor, MF | 5.62 MΩ 1% 1/4 W | 325397 |
| R105 | Resistor, MF | 24.3 kΩ 1% | 341437 |
| R106 | Resistor, MF | 80.6 kΩ 1% | 341487 |
| R107 | Resistor, MF | 374 kΩ 1% | 341555 |
| R108 | Resistor, MF | 294 kΩ 1% | 341545 |
| R109 | Resistor, MF | 1.0 MΩ 1% | 342600 |
| R110 | Resistor, Comp. | 91 kΩ 5% | 343492 |
| R111 | Resistor, Comp. | 47 kΩ 5% | 343465 |
| R112 | Resistor, Comp. | 33 kΩ 5% | 343450 |
| R113 | Resistor, Comp. | 300 kΩ 5% | 343546 |
| R114 | Resistor, MF | 169 Ω 1% | 341222 |
| R115 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R116 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R117 | Resistor, Comp. | 33 kΩ 5% | 343450 |
| R118 | Resistor, MF | 15.0 kΩ 1% | 341417 |
| R119 | Resistor, Comp. | 15 kΩ 5% | 343417 |
| R120 | Resistor, Comp. | 3.6 kΩ 5% | 343353 |
| R121 | Resistor, Comp. | 3 kΩ 5% | 343346 |
| R122 | Resistor, Comp. | 1 MΩ 5% | 343600 |
| R123 | Resistor, Comp. | 2.7 kΩ 5% | 343341 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | AMPLIFIER PC BOARD (CONTINUED) | | |
| R124 | Resistor, Comp. | 5.6 kΩ 5% | 343372 |
| R125 | Resistor, Comp. | 5.6 kΩ 5% | 343372 |
| R126 | Resistor, Comp. | 1 kΩ 5% | 344300 |
| R127 | Resistor, Comp. | 5.1 kΩ 5% | 343368 |
| R128 | Resistor, Comp. | 15 kΩ 5% | 343417 |
| R129 | Resistor, Comp. | 1 kΩ 5% | 344300 |
| R130 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R131 | Resistor, MF | 30.1 kΩ 1% | 341446 |
| R132 | Resistor, MF | 3.01 kΩ 1% | 341346 |
| R133 | Resistor, MF | 301 Ω 1% | 341246 |
| R134 | Resistor, MF | 33.2 Ω 1% | 341150 |
| R135 | Resistor, Comp. | 1 MΩ 5% | 343600 |
| R136 | Resistor, Comp. | 1 kΩ 5% | 343300 |
| R137 | Resistor, Comp. | 1 kΩ 5% | 343300 |
| R138 | Resistor, Comp. | 15 kΩ 5% | 343417 |
| R139 | Resistor, MF | 3.32 kΩ 1% | 341350 |
| R140 | Resistor, Var. | 1 kΩ ±10% 0.5 W | 311316 |
| R141 | Resistor, MF | 3.01 kΩ 1% | 341346 |
| R142 | Resistor, MF | 3.32 kΩ 1% | 341350 |
| R143 | Resistor, Var. | 1 kΩ ±10% 0.5 W | 311316 |
| R144 | Resistor, MF | 3.01 kΩ 1% | 341346 |
| R145 | Resistor, MF | 9.09 kΩ 1% | 341392 |
| R149 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R150 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R151 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R152 | Not Used | | |
| R153 | Not Used | | |
| R154 | Not Used | | |
| R155 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R156 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R157 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R158 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R159 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R160 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R161 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R162 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R163 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R164 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R165 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R166 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R167 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R168 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R169 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R170 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R171 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R172 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R173 | Resistor, Comp. | 160 kΩ 5% | 343520 |
| R174 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R175 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R176 | Resistor, Comp. | 160 kΩ 5% | 343520 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | AMPLIFIER PC BOARD (CONTINUED) | | |
| R177 | Resistor, Comp. | 39 kΩ 5% | 343457 |
| R178 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R179 | Resistor, Var. | 10 kΩ 10% 0.5 W | 311328 |
| R180 | Resistor, MF | 46.4 kΩ 1% | 341464 |
| R181 | Resistor, Comp. | 1.8 kΩ 5% | 343325 |
| R182 | Resistor, Comp. | 1.8 kΩ 5% | 343325 |
| | CHOPPER DRIVER PC BOARD | | |
| A201 | Op. Amp. | LM310H | 535005 |
| C201 | Capacitor, PC | 100 nF ±10% 50 V | 234046 |
| C202 | Capacitor, PE | 6.8 nF ±10% 200 V | 234044 |
| C203 | Capacitor, Mica | 100 pF ±5% 500 V | 200001 |
| C204 | Capacitor, Mica | 100 pF ±5% 500 V | 200001 |
| C205 | Capacitor, PE | 22 nF ±10% 200 V | 230101 |
| C206 | Capacitor, PC | 100 nF ±10% 50 V | 234046 |
| C207 | Capacitor, Mica | 100 pF ±5% 500 V | 200001 |
| C208 | Capacitor, PC | 100 nF ±10% 50 V | 234046 |
| C209 | Capacitor, Cer. | 10 nF 100 V | 224119 |
| C210 | Capacitor, Cer. | 10 nF 100 V | 224119 |
| C211 | Capacitor, PE | 22 nF 10% 200 V | 230101 |
| C212 | Capacitor, PC | 470 nF ±10% 50 V | 234128 |
| C213 | Capacitor, Mica | 100 pF ±5% 500 V | 200001 |
| C214 | Capacitor, Elec. | 50 µF +75% -10% 25 V | 283159 |
| C215 | Capacitor, Elec. | 50 µF +75% -10% 25 V | 283159 |
| C216 | Capacitor, Elec. | 50 µF +75% -10% 25 V | 283159 |
| C217 | Capacitor, Elec. | 150 µF -10% +75% 15 V | 283307 |
| CR201 through CR218 | Diode, Sig. | 1N914 | 530058 |
| CR219 | Diode, Sig. | FDH-300 | 530052 |
| Q201 | Transistor, Uni. | 2N4871 | 528051 |
| Q202 | Transistor, NPN | MPS-A20 | 528043 |
| Q203 | Transistor, PNP | 2N5087 | 528042 |
| Q204 | Transistor, NPN | 2N5088 | 528047 |
| Q205 | Transistor, NPN | MPS-A20 | 528043 |
| Q206 | Transistor, FET | MPS-A12 | 528052 |
| Q207 | Transistor, NPN | MPS-A20 | 528043 |
| Q208 | Transistor, FET | Selected | 528093 |
| Q209 | Transistor, NPN | MPS-A20 | 528043 |
| Q210 | Transistor, FET | Selected | 528093 |
| Q211 | Transistor, FET | 2N5949 | 528019 |
| Q212 | Transistor, NPN | MPS-A20 | 528043 |
| Q213 | Transistor, NPN | 2N5308 | 528050 |
| Q214 | Transistor, NPN | 2N5308 | 528050 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | CHOPPER DRIVER PC BOARD (CONTINUED) | | |
| R201 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R202 | Resistor, Comp. | 22 kΩ 5% | 343433 |
| R203 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R204 | Resistor, Comp. | 100 Ω 5% | 343200 |
| R205 | Resistor, Comp. | 33 kΩ 5% | 343450 |
| R206 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R207 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R208 | Resistor, Comp. | 3.3 kΩ 5% | 343350 |
| R209 | Resistor, Comp. | 4.7 kΩ 5% | 343365 |
| R210 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R211 | Resistor, Comp. | 150 kΩ 5% | 343517 |
| R212 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R213 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R214 | Resistor, Comp. | 22 kΩ 5% | 343433 |
| R215 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R216 | Resistor, Comp. | 270 kΩ 5% | 343541 |
| R217 | Resistor, Comp. | 240 kΩ 5% | 343537 |
| R218 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R219 | Resistor, Comp. | 15 kΩ 5% | 343417 |
| R220 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R221 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R222 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R223 | Resistor, Comp. | 4.7 kΩ 5% | 343365 |
| R224 | Resistor, Comp. | 12 kΩ 5% | 343408 |
| R225 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R226 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R227 | Resistor, Comp. | 15 kΩ 5% | 343417 |
| R228 | Resistor, Comp. | 10 kΩ 5% | 343400 |
| R229 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R230 | Resistor, Comp. | 12 kΩ 5% | 343408 |
| R231 | Resistor, Comp. | 4.7 kΩ 5% | 343365 |
| R232 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R233 | Resistor, Var. | 2 kΩ 20% 1/2 W | 311285 |
| R234 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R235 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R236 | Resistor, Comp. | 27 kΩ 5% | 343441 |
| R237 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R238 | Resistor, Comp. | 100 kΩ 5% | 343500 |
| R239 | Resistor, Comp. | 1.6 kΩ 5% | 343320 |
| R240 | Resistor, Comp. | 300 Ω 5% | 343246 |
| R241 | Resistor, Comp. | 200 Ω 5% 1 W | 302082 |
| R242 | Resistor, Comp. | 150 kΩ 5% | 343517 |
| R243 | Resistor, Comp. | 510 kΩ 5% | 343568 |
| R244 | Resistor, Var. | 50 kΩ 20% 1/2 W | 311282 |
| R245 | Resistor, Comp. | 47 Ω 5% | 343165 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | SHAPING AMPLIFIER PC BOARD | | |
| A301 | Op. Amp. | LM301AN | 535012 |
| C301 | Capacitor, Cer. | 10 nF 100 V | 224119 |
| C302 | Capacitor, Mica | 33 pF ±5% 500 V | 200049 |
| C303 | Capacitor, Cer. | 10 nF 100 V | 224119 |
| CR301 through CR308 | Diode, Sig. | 1N914 | 530058 |
| Q301 | Transistor, FET | 2N5949 | 528019 |
| Q302 | Transistor, FET | 2N5949 | 528019 |
| Q303 | Transistor, FET | 2N5949 | 528019 |
| Q304 | Transistor, PNP | 2N5087 | 528042 |
| Q305 | Transistor, FET | 2N5949 | 528019 |
| Q306 | Transistor, PNP | 2N5087 | 528042 |
| Q307 | Transistor, FET | 2N5949 | 528019 |
| Q308 | Transistor, PNP | 2N5087 | 528042 |
| Q309 | Transistor, FET | 2N5949 | 528019 |
| Q310 | Transistor, PNP | 2N5087 | 528042 |
| Q311 | Transistor, FET | 2N5949 | 528019 |
| Q312 | Transistor, PNP | 2N5087 | 528042 |
| Q313 through Q316 | Transistor, FET | 2N5949 | 528019 |
| Q317 | Transistor, PNP | 2N5087 | 528042 |
| Q318 | Transistor, NPN | 2N5088 | 528047 |
| Q319 | Transistor, PNP | 2N5087 | 528042 |
| Q320 | Transistor, NPN | 2N5088 | 528047 |
| Q321 | Transistor, PNP | 2N5087 | 528042 |
| Q322 | Transistor, PNP | 2N5087 | 528042 |
| Q323 | Transistor, FET | 2N5949 | 528019 |
| Q324 | Transistor, FET | 2N5949 | 528019 |
| Q325 | Transistor, PNP | 2N5087 | 528042 |
| Q326 | Transistor, FET | 2N5949 | 528019 |
| Q327 | Transistor, PNP | 2N5087 | 528042 |
| Q328 | Transistor, FET | 2N5949 | 528019 |
| Q329 | Transistor, PNP | 2N5087 | 528042 |
| Q330 | Transistor, FET | 2N5949 | 528019 |
| Q331 | Transistor, FET | 2N5949 | 528019 |
| Q332 | Transistor, PNP | 2N5087 | 528042 |
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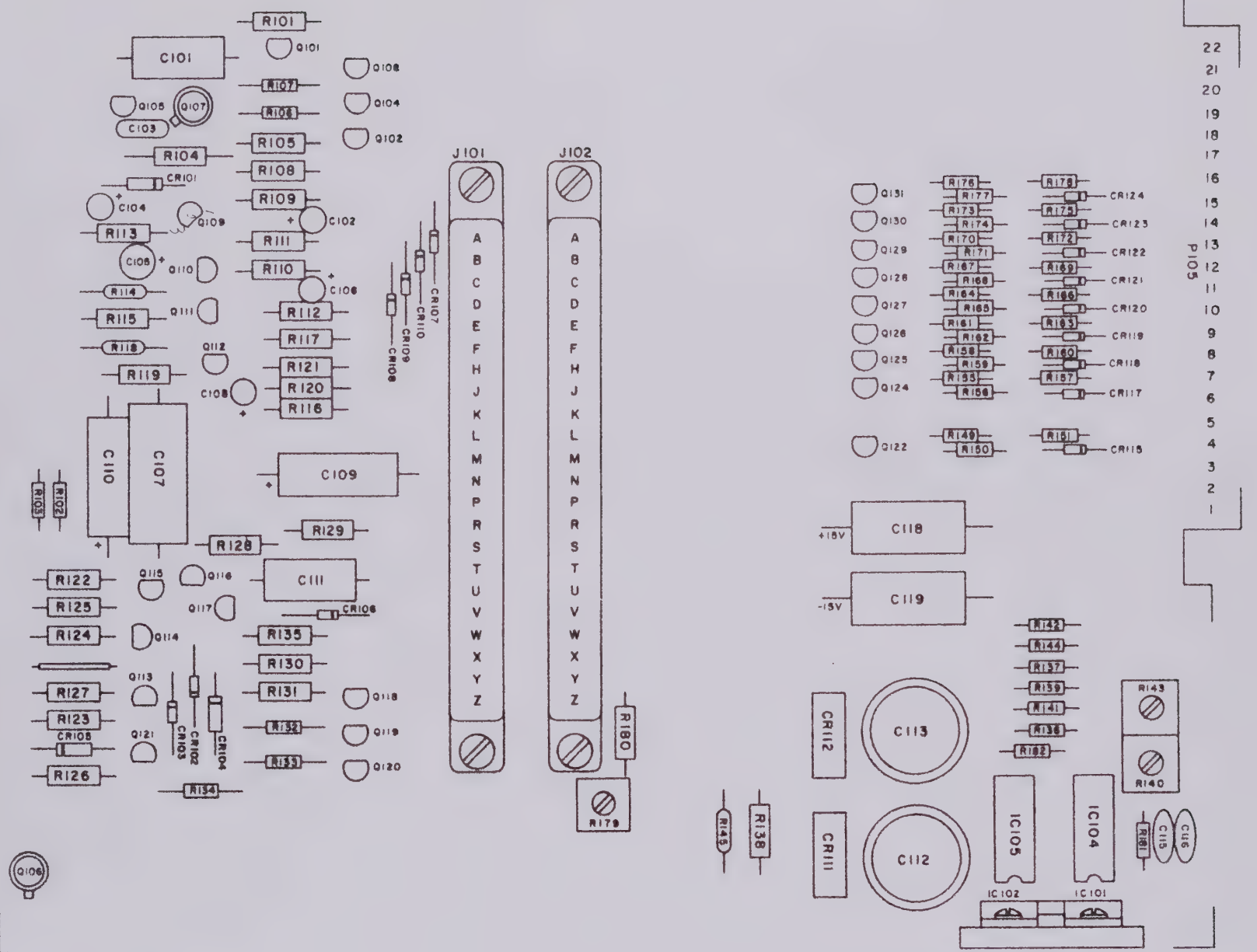
| Q335 | Transistor, FET | 2N5949 | 528019 |
| Q336 | Transistor, FET | 2N5949 | 528019 |
| Q337 | Transistor, PNP | 2N5087 | 528042 |
| Q338 | Transistor, PNP | 2N5087 | 528042 |
| Q339 | Transistor, PNP | 2N5087 | 528042 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | SHAPING AMPLIFIER PC BOARD (CONTINUED) | | |
| R301 | Resistor, Comp. | 130 Ω 5% | 343211 |
| R302 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R303 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R304 | Resistor, MF | 10 kΩ ±1% | 341400 |
| R305 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R306 | Resistor, MF | 51.1 kΩ ±1% | 341468 |
| R307 | Resistor, MF | 2.49 kΩ ±1% | 341338 |
| R308 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R309 | Resistor, MF | 28.7 kΩ ±1% | 341444 |
| R310 | Resistor, MF | 200 kΩ ±1% | 341529 |
| R311 | Resistor, MF | 100 kΩ ±1% | 341500 |
| R312 | Resistor, MF | 40.2 kΩ ±1% | 341458 |
| R313 | Resistor, MF | 191 kΩ ±1% | 341527 |
| R314 | Resistor, MF | 11 kΩ ±1% | 341404 |
| R315 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R316 | Resistor, MF | 29.4 kΩ ±1% | 341445 |
| R317 | Resistor, MF | 95.3 kΩ ±1% | 341494 |
| R318 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R319 | Resistor, MF | 28.0 kΩ ±1% | 341443 |
| R320 | Resistor, MF | 64.9 kΩ ±1% | 341478 |
| R321 | Resistor, MF | 1.00 MΩ ±1% | 342600 |
| R322 | Resistor, MF | 26.1 kΩ ±1% | 341440 |
| R323 | Resistor, MF | 46.4 kΩ ±1% | 341464 |
| R324 | Resistor, MF | 10 kΩ ±1% | 341400 |
| R325 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R326 | Resistor, MF | 45.3 kΩ ±1% | 341463 |
| R327 | Resistor, MF | 2.49 kΩ ±1% | 341338 |
| R328 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R329 | Resistor, Comp. | 270 kΩ 5% | 343541 |
| R330 | Resistor, MF | 21.5 kΩ ±1% | 341432 |
| R331 | Resistor, MF | 237 kΩ ±1% | 341536 |
| R332 | Resistor, Comp. | 18 kΩ 5% | 343425 |
| R333 | Resistor, MF | 26.1 kΩ ±1% | 341440 |
| R334 | Resistor, MF | 154 kΩ ±1% | 341518 |
| R335 | Resistor, Comp. | 47 kΩ 5% | 343465 |
| R336 | Resistor, MF | 54.9 kΩ ±1% | 341471 |
| R337 | Resistor, MF | 191 kΩ ±1% | 341527 |
| R338 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R339 | Resistor, MF | 82.5 kΩ ±1% | 341488 |
| R340 | Resistor, MF | 178 kΩ ±1% | 341524 |
| R341 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R342 | Resistor, MF | 17.8 kΩ ±1% | 341424 |
| R343 | Resistor, MF | 2.74 kΩ ±1% | 341342 |
| R344 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R345 | Resistor, MF | 24.3 kΩ ±1% | 341437 |
| R346 | Resistor, MF | 232 kΩ ±1% | 341535 |
| R347 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R348 | Resistor, MF | 95.3 kΩ ±1% | 341494 |

| Reference | Description | | Part No. |
|---|---|---|---|
| | SHAPING AMPLIFIER PC BOARD (CONTINUED) | | |
| R349 | Resistor, MF | 453 kΩ ±1% | 341563 |
| R350 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R351 | Resistor, MF | 200 kΩ ±1% | 341529 |
| R352 | Resistor, MF | 634 kΩ ±1% | 342577 |
| R353 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R354 | Resistor, MF | 14.3 kΩ ±1% | 341415 |
| R355 | Resistor, MF | 2.49 kΩ ±1% | 341338 |
| R356 | Resistor, MF | 34.8 kΩ ±1% | 341452 |
| R357 | Resistor, MF | 523 kΩ ±1% | 342569 |
| R358 | Resistor, Comp. | 4.7 MΩ 5% | 343665 |
| R359 | Resistor, MF | 162 kΩ ±1% | 341520 |
| R360 | Resistor, MF | 806 kΩ ±1% | 342587 |
| R361 | Resistor, MF | 10 kΩ ±1% | 341400 |
| R362 | Resistor, MF | 2.74 kΩ ±1% | 341342 |
| R363 | Resistor, Var. | 1 kΩ 10% 1 W | 311256 |
| R364 | Resistor, MF | 127 kΩ ±1% | 341510 |
| R365 | Resistor, MF | 604 kΩ ±1% | 342575 |
| RT301 | Thermistor | 100 Ω ±10% | 325005 |
| | REAR PANEL, SUB PANEL, CHOPPER SOCKET | | |
| C401 | Capacitor, Mylar | 100 nF 10% 50 V | 234046 |
| C402 | Capacitor, Mylar | 100 nF 10% 50 V | 234046 |
| DS401 | Lamp | Tung-Sol No. 349 | 545107 |
| DS402 | Lamp | Tung-Sol No. 349 | 545107 |
| F401 | Fuse, Slo-Blo | 1/10 Amp 250 V | 545519 |
| F401 | Fuse, Slo-Blo | 1/16 Amp 250 V | 545518 |
| G401 | Chopper, Special | --- | 540126 |
| J401 | Receptacle | Amphenol No. 80-PC-2FT | 479119 |
| M401 | Meter & Scale | API | 554216 |
| R401 | Resistor, Var. | 5 kΩ 20% 2 W | 311255 |
| S401 | Switch, Pushbutton | Centralab | 465146 |
| S402 | Switch, Slide | Switchcraft | 465134 |
| T401 | Power Transformer | Boonton Electronics | 446068 |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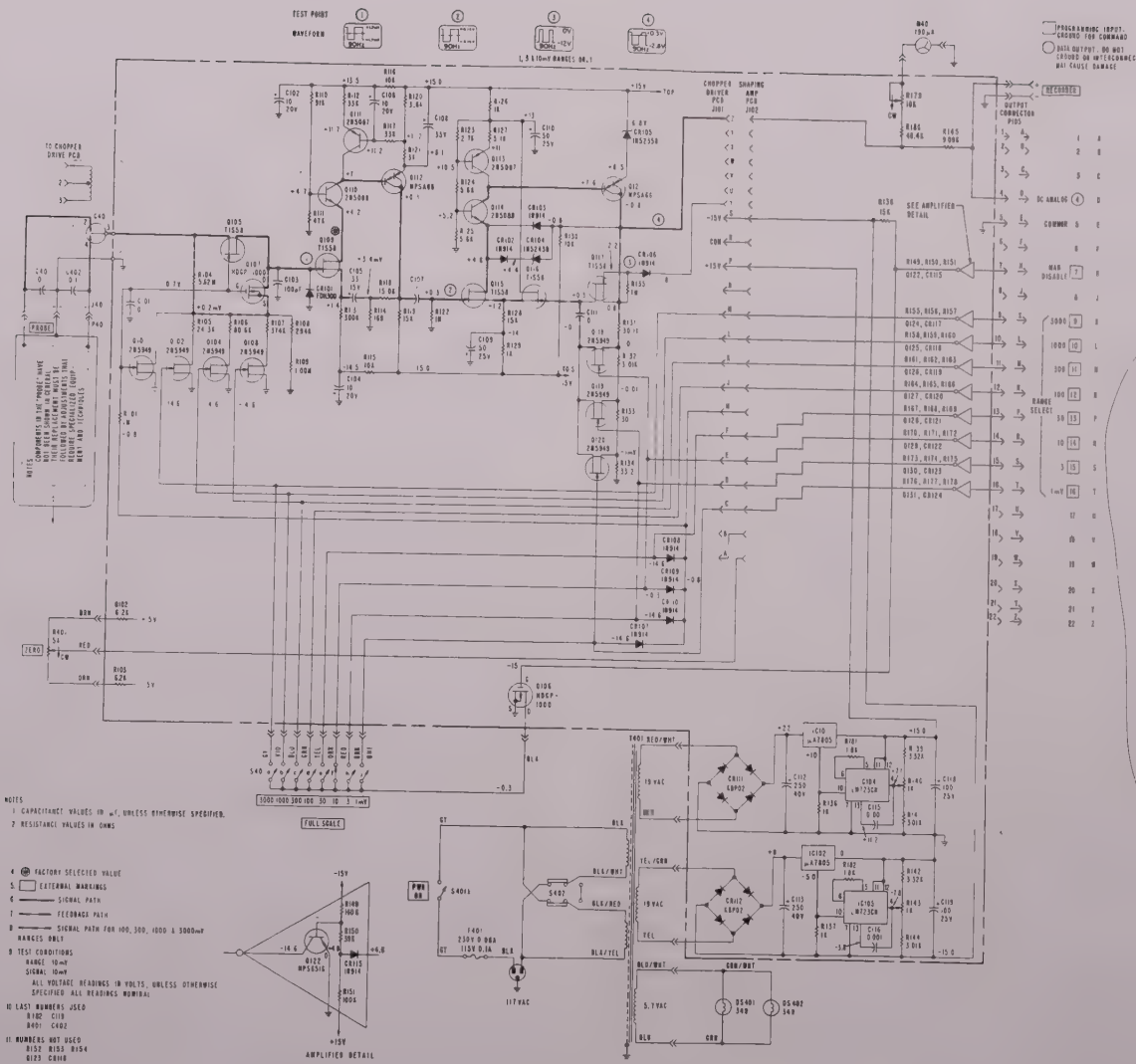

CAUTION
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SEE ISSUE SHEET.
7-12-82

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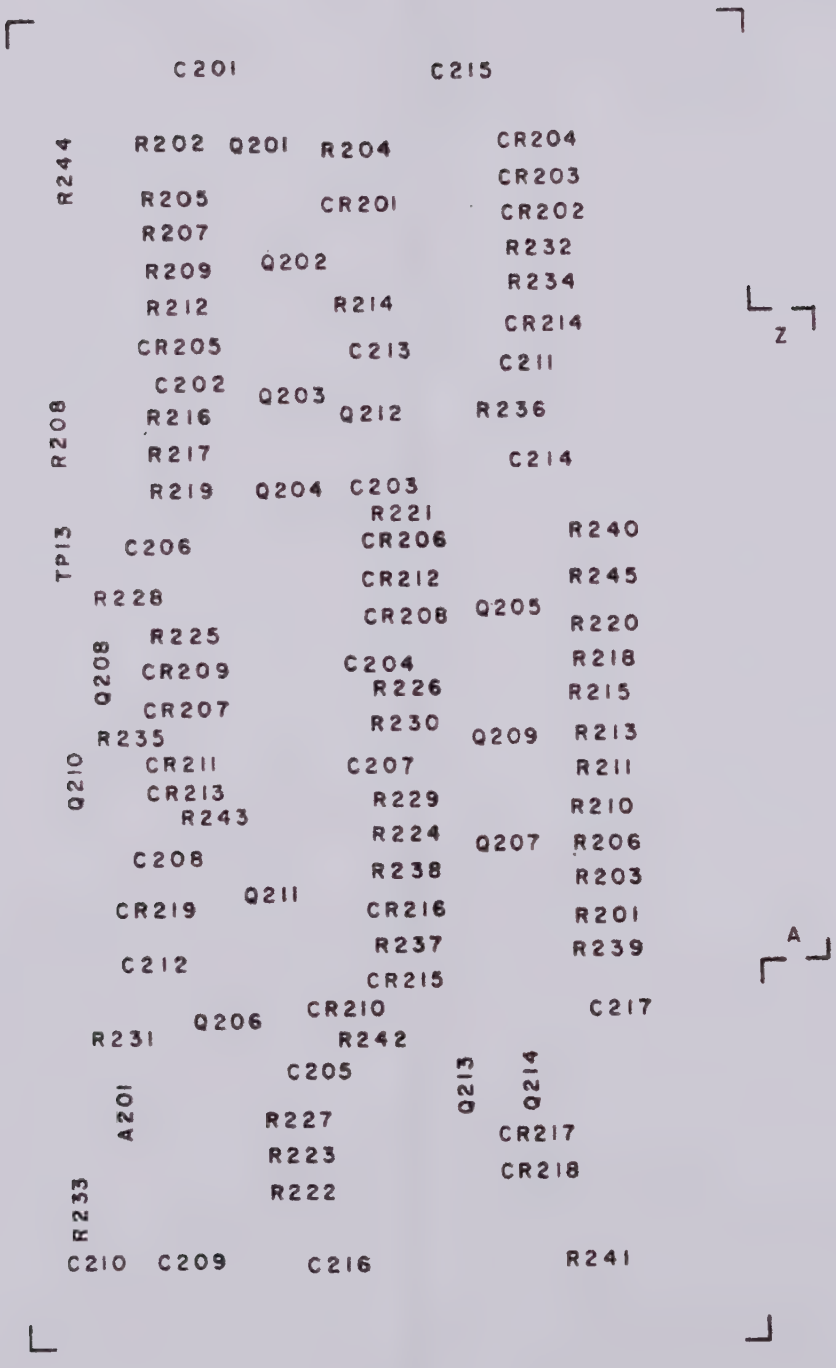
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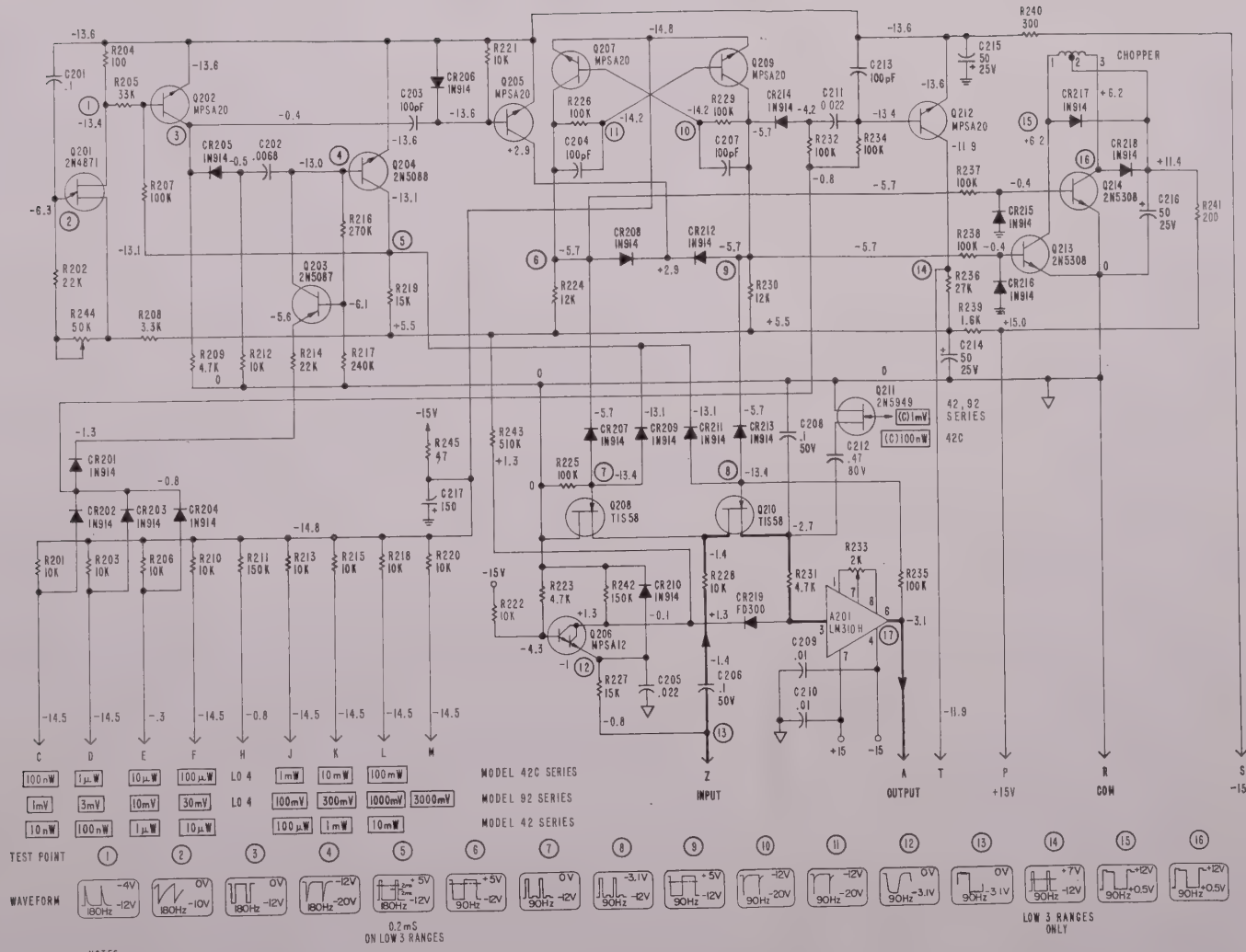
R239
C212
CR215
C217
CR210
Q206
R231
R242
C205
Q213
Q214
A201
R227
CR217
R223
CR218
R233
R222
C210
C209
C216
R241



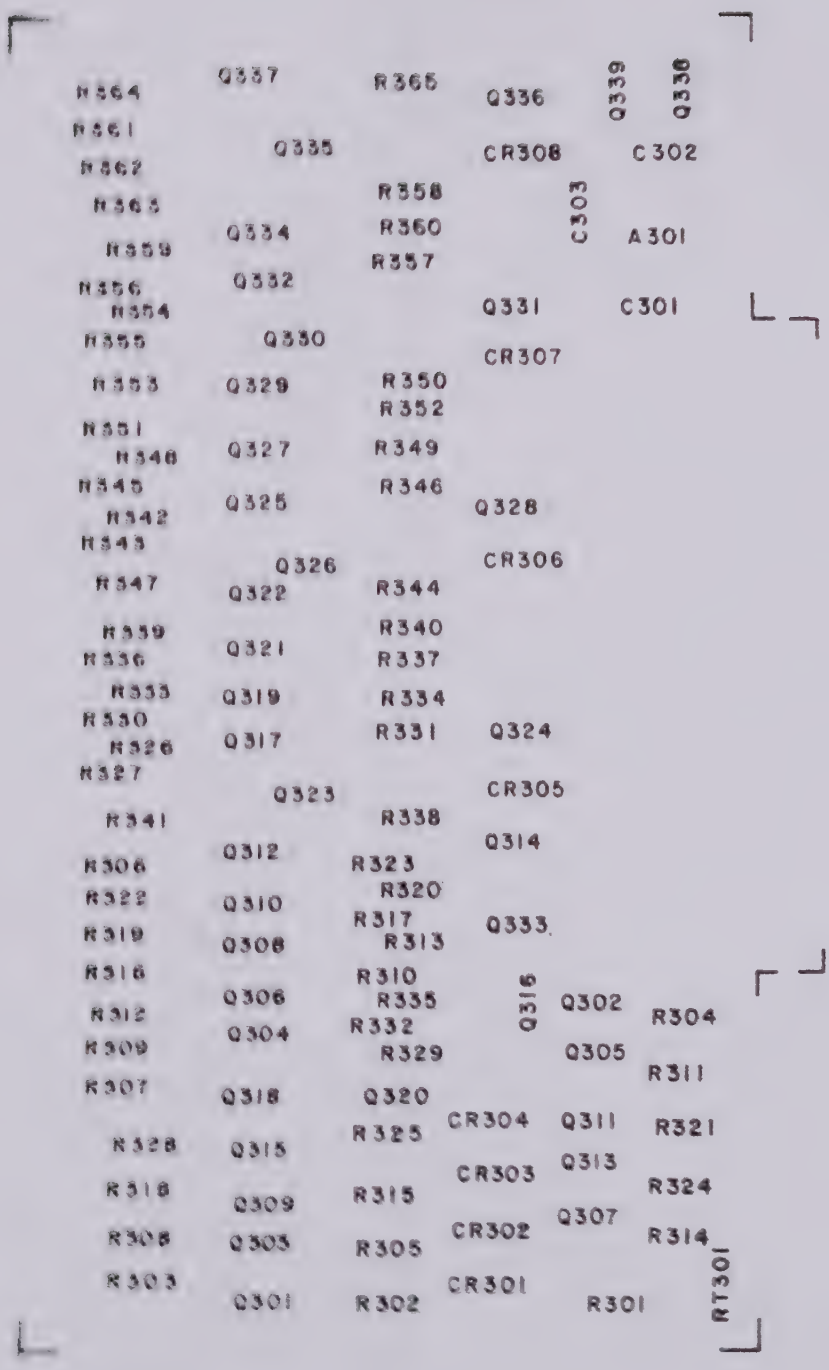

P101
CONNECTS TO J101
ON AMP. BD 565675

| INSTRUMENT | SCHEMATIC |
|---|---|
| 42B | 830636 |
| 42BB | 830658 SHT. 1 |
| 42BD | 830592 SHT. 1 |
| 42B-18 | 830640 |
| 42B-19 | 830641 |
| 92B | 830605 |
| 92BD | 830581 SHT. 1 |
| 42C | 830636 |
| 42CD | 830592 SHT. 1 |
| 42CB | 830658 SHT. 1 |

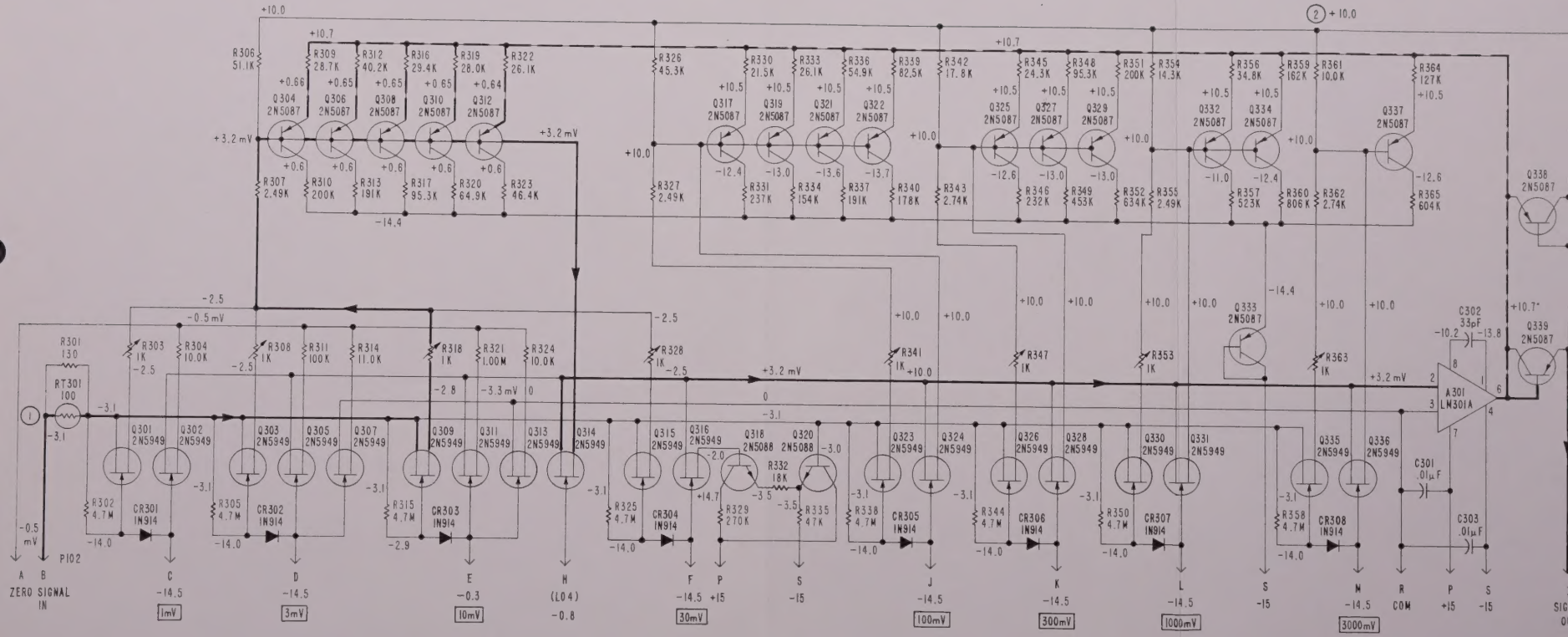
NOTES

1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS.
3. ▭ EXTERNAL MARKINGS.
4. ▽ COMMON
5. ——— SIGNAL PATH
6. TEST CONDITIONS
   10mV RANGE, 10mV SIGNAL } 42, 92 SERIES
   10μW RANGE, 10μW SIGNAL } 42C ONLY
   ALL VOLTAGES NOMINAL. ALL READINGS IN VOLTS, UNLESS OTHERWISE SPECIFIED.
8. LAST NUMBERS USED:
   R245 C217 Q214 CR219 A201

Schematic, Chopper Drive
D830581L Sheet 3 of 3


R364
Q337
R365
Q336
Q339
Q336
R361
Q335
CR308
C302
R362
R358
R363
C303
Q334
R360
A301
R359
R357
R356
Q332
R354
Q331
C301
R355
Q330
CR307
R353
Q329
R350
R352
R351
R348
Q327
R349
R345
R346
Q325
Q328
R342
R343
Q326
CR306
R347
Q322
R344
R339
R340
R336
Q321
R337
R333
Q319
R334
R330
R326
Q317
R331
Q324
R327
Q323
CR305
R341
R338
Q314
R306
Q312
R323
R322
R320
Q310
R317
Q333
R319
Q308
R313
R316
R310
Q316
Q302
R304
R312
Q306
R335
R309
Q304
R332
Q305
R311
R307
Q318
Q320
CR304
Q311
R321
R328
Q315
R325
CR303
Q313
R318
Q309
R315
R324
Q307
R308
Q303
CR302
R314
R305
RT301
R303
CR301
Q301
R302
R301

NOTES:
1. RESISTANCE VALUES IN OHMS.
2. SIGNAL PATH ——
3. FEEDBACK PATH — — —
4. ▭ EXTERNAL MARKINGS
5. LAST NUMBER USED:
R365 C303 Q339 CR308




Schematic, Shaping Amp.
D830456L Sheet 3 of 3

MP MASTER
MA34354